

## PATENT COOPERATION TREATY

PCT

NOTIFICATION OF THE RECORDING  
OF A CHANGE(PCT Rule 92bis.1 and  
Administrative Instructions, Section 422)

From the INTERNATIONAL BUREAU

To:

LARSSON, Hakan  
ABB AB  
Patent  
S-721 78 Västerås  
SUÈDE

Date of mailing (day/month/year) 27 September 2000 (27.09.00)	<b>IMPORTANT NOTIFICATION</b>
Applicant's or agent's file reference KN8569WO	
International application No. PCT/SE99/02268	International filing date (day/month/year) 06 December 1999 (06.12.99)

1. The following indications appeared on record concerning: <input type="checkbox"/> the applicant <input type="checkbox"/> the inventor <input checked="" type="checkbox"/> the agent <input type="checkbox"/> the common representative		
Name and Address ABB AB Patent Gideonsbergsgatan 2 S-721 78 Västerås Sweden	State of Nationality	State of Residence
	Telephone No. +46 21 32 30 00	
	Facsimile No. +46 21 18 13 86	
	Teleprinter No.	
2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning: <input type="checkbox"/> the person <input checked="" type="checkbox"/> the name <input checked="" type="checkbox"/> the address <input type="checkbox"/> the nationality <input type="checkbox"/> the residence		
Name and Address LARSSON, Hakan ABB AB Patent S-721 78 Västerås Sweden	State of Nationality	State of Residence
	Telephone No. +46 21 32 30 00	
	Facsimile No. +46 21 18 13 86	
	Teleprinter No.	
3. Further observations, if necessary:		
4. A copy of this notification has been sent to: <input checked="" type="checkbox"/> the receiving Office <input type="checkbox"/> the designated Offices concerned <input type="checkbox"/> the International Searching Authority <input checked="" type="checkbox"/> the elected Offices concerned <input checked="" type="checkbox"/> the International Preliminary Examining Authority <input type="checkbox"/> other:		

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No.: (41-22) 740.14.35	Authorized officer R. Chrem Telephone No.: (41-22) 338.83.38
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## PATENT COOPERATION TREATY

PCT

NOTIFICATION OF THE RECORDING  
OF A CHANGE(PCT Rule 92bis.1 and  
Administrative Instructions, Section 422)

From the INTERNATIONAL BUREAU

To:

BJERKÉNS PATENTBYRÅ KB  
Östermalmsgatan 58  
S-114 50 Stockholm  
SUÈDE

Date of mailing (day/month/year) 03 April 2001 (03.04.01)	IMPORTANT NOTIFICATION
Applicant's or agent's file reference KN8569WO	
International application No. PCT/SE99/02268	International filing date (day/month/year) 06 December 1999 (06.12.99)

1. The following indications appeared on record concerning:

☒ the applicant    ☐ the inventor    ☐ the agent    ☐ the common representative

Name and Address ABB ATOM AB S-721 63 Västerås Sweden	State of Nationality SE	State of Residence SE
	Telephone No.	
	Facsimile No.	
	Teleprinter No.	

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

☐ the person    ☒ the name    ☐ the address    ☐ the nationality    ☐ the residence

Name and Address WESTINGHOUSE ATOM AB S-721 63 Västerås Sweden	State of Nationality SE	State of Residence SE
	Telephone No.	
	Facsimile No.	
	Teleprinter No.	

3. Further observations, if necessary:

4. A copy of this notification has been sent to:

☒ the receiving Office    ☐ the designated Offices concerned  
☐ the International Searching Authority    ☒ the elected Offices concerned  
☐ the International Preliminary Examining Authority    ☐ other:

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No.: (41-22) 740.14.35	Authorized officer C. Cupello Telephone No.: (41-22) 338.83.38
---	--

## PATENT COOPERATION TREATY

PCT

NOTIFICATION OF THE RECORDING  
OF A CHANGE(PCT Rule 92bis.1 and  
Administrative Instructions, Section 422)

From the INTERNATIONAL BUREAU

To:

BJERKÉNS PATENTBYRÅ KB  
Östermalmsgatan 58  
S-114 50 Stockholm  
SUÈDE

Date of mailing (day/month/year) 03 April 2001 (03.04.01)	<b>IMPORTANT NOTIFICATION</b>
Applicant's or agent's file reference KN8569WO	
International application No. PCT/SE99/02268	International filing date (day/month/year) 06 December 1999 (06.12.99)

<b>1. The following indications appeared on record concerning:</b> <input type="checkbox"/> the applicant <input type="checkbox"/> the inventor <input checked="" type="checkbox"/> the agent <input type="checkbox"/> the common representative		
Name and Address LARSSON, Håkan ABB AB Patent S-721 78 Västerås Sweden	State of Nationality	State of Residence
	Telephone No.	
	Facsimile No.	
	Teleprinter No.	
<b>2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:</b> <input checked="" type="checkbox"/> the person <input checked="" type="checkbox"/> the name <input checked="" type="checkbox"/> the address <input type="checkbox"/> the nationality <input type="checkbox"/> the residence		
Name and Address BJERKÉNS PATENTBYRÅ KB Östermalmsgatan 58 S-114 50 Stockholm Sweden	State of Nationality	State of Residence
	Telephone No. +46 8 662 08 70	
	Facsimile No. +46 8 663 02 60	
	Teleprinter No.	
<b>3. Further observations, if necessary:</b>		
<b>4. A copy of this notification has been sent to:</b> <input checked="" type="checkbox"/> the receiving Office <input type="checkbox"/> the designated Offices concerned <input type="checkbox"/> the International Searching Authority <input checked="" type="checkbox"/> the elected Offices concerned <input type="checkbox"/> the International Preliminary Examining Authority <input type="checkbox"/> other:		

<b>The International Bureau of WIPO</b> 34, chemin des Colombettes 1211 Geneva 20, Switzerland  Facsimile No.: (41-22) 740.14.35	Authorized officer  C. Cupello  Telephone No.: (41-22) 338.83.38
--	--

## PATENT COOPERATION TREATY

PCT

## NOTIFICATION OF ELECTION

(PCT Rule 61.2)

From the INTERNATIONAL BUREAU

To:

Assistant Commissioner for Patents  
 United States Patent and Trademark  
 Office  
 Box PCT  
 Washington, D.C.20231  
 ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

<b>Date of mailing (day/month/year)</b> 04 September 2000 (04.09.00)	
<b>International application No.</b> PCT/SE99/02268	<b>Applicant's or agent's file reference</b> KN8569WO
<b>International filing date (day/month/year)</b> 06 December 1999 (06.12.99)	<b>Priority date (day/month/year)</b> 23 December 1998 (23.12.98)
<b>Applicant</b> BERNANDER, Örjan et al	

1. The designated Office is hereby notified of its election made:



in the demand filed with the International Preliminary Examining Authority on:

10 July 2000 (10.07.00)



in a notice effecting later election filed with the International Bureau on:

2. The election ☒ was

was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

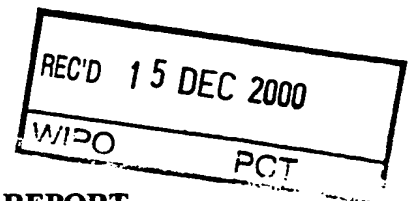
<b>The International Bureau of WIPO</b> 34, chemin des Colombettes 1211 Geneva 20, Switzerland  Facsimile No.: (41-22) 740.14.35	<b>Authorized officer</b>  Charlotte ENGER  Telephone No.: (41-22) 338.83.38
--	--

## PATENT COOPERATION TREATY

## PCT

## INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)



3

Applicant's or agent's file reference KN 8569 WO	<b>FOR FURTHER ACTION</b>	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/SE99/02268	International filing date (day/month/year) 06.12.1999	Priority date (day/month/year) 23.12.1998
International Patent Classification (IPC) or national classification and IPC <sub>7</sub> G 21 C 7/113		
Applicant ABB Atom AB et al		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 3 sheets, including this cover sheet.

☐ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of \_\_\_\_\_ sheets.

3. This report contains indications relating to the following items:

- I ☒ Basis of the report
- II ☐ Priority
- III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- IV ☐ Lack of unity of invention
- V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- VI ☐ Certain documents cited
- VII ☐ Certain defects in the international application
- VIII ☐ Certain observations on the international application

Date of submission of the demand  10.07.2000	Date of completion of this report  21.11.2000
Name and mailing address of the IPEA/SE Patent- och registreringsverket Box 5055 S-102 42 STOCKHOLM Facsimile No. 08-667 72 88	Authorized officer  Tomas Lund/ELY Telephone No. 08-782 25 00

# INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application N .

PCT/SE99/02268

## I. Basis of the report

### 1. With regard to the elements of the international application:\*

☒ the international application as originally filed

☐ the description:

pages \_\_\_\_\_, as originally filed

pages \_\_\_\_\_, filed with the demand

pages \_\_\_\_\_, filed with the letter of \_\_\_\_\_

☐ the claims:

pages \_\_\_\_\_, as originally filed

pages \_\_\_\_\_, as amended (together with any statement) under article 19

pages \_\_\_\_\_, filed with the demand

pages \_\_\_\_\_, filed with the letter of \_\_\_\_\_

☐ the drawings:

pages \_\_\_\_\_, as originally filed

pages \_\_\_\_\_, filed with the demand

pages \_\_\_\_\_, filed with the letter of \_\_\_\_\_

☐ the sequence listing part of the description:

pages \_\_\_\_\_, as originally filed

pages \_\_\_\_\_, filed with the demand

pages \_\_\_\_\_, filed with the letter of \_\_\_\_\_

### 2. With regard to the language, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language english which is:

☐ the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).

☒ the language of publication of the international application (under Rule 48.3(b)).

☐ the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

### 3. With regard to any nucleotide and/or amino acid sequence disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

☐ contained in the international application in written form.

☐ filed together with the international application in computer readable form.

☐ furnished subsequently to this Authority in written form.

☐ furnished subsequently to this Authority in computer readable form.

☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

### 4. ☐ The amendments have resulted in the cancellation of:

☐ the description, pages \_\_\_\_\_

☐ the claims, Nos. \_\_\_\_\_

☐ the drawings, sheet/fig \_\_\_\_\_

### 5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2 (c)).\*\*

\* Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).

\*\* Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.

## INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.

PCT/SE99/02268

**V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement****1. Statement**

Novelty (N)	Claims	<u>1-12</u>	YES
	Claims	_____	NO
Inventive step (IS)	Claims	<u>1-12</u>	YES
	Claims	_____	NO
Industrial applicability (IA)	Claims	<u>1-12</u>	YES
	Claims	_____	NO

**2. Citations and explanations (Rule 70.7)**

The claimed invention relates to a control rod for boiling water reactors. The control rod comprises four absorber blades, which form an orthogonal cross with a cruciform centre. The capacity of the absorber blades to absorb neutrons is lower in the upper part of the control rod than in the lower part. At the upper part of the control rod the absorber blades comprise a radially inner part that lacks absorber material and a radially outer part that is provided with absorber material.

The object of the claimed invention is to achieve a control rod for a nuclear reactor which reduces the risk of fuel failure, especially on the fuel rods near the cruciform centre, when the control rod is extracted from the reactor core.

CH, A5, 665 046, cited in the International Search Report, discloses a control rod comprising four absorber blades, which form an orthogonal cross with a cruciform centre. The absorber blades comprise a radially inner part that lacks absorber material and a radially outer part that is provided with absorber material (see figure 2). However, the absorber material is evenly distributed on the longitudinal direction of the absorber blades, whereas in the claimed invention the quantity of absorber material is lower in the upper part of the absorber blades of the control rod.

Therefore, the claimed invention is novel, it is not regarded obvious to a person skilled in the art and there will be no doubts about its usefulness. Therefore, the stipulated criteria regarding novelty, inventive step and industrial applicability under PCT Article 33 (1) are fulfilled for the claimed invention.

# PATENT COOPERATION TREATY

## PCT

### INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference <b>KN 8569 WO</b>	<b>FOR FURTHER ACTION</b> See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)	
International application No. <b>PCT/SE99/02268</b>	International filing date ( <i>day/month/year</i> ) <b>06.12.1999</b>	Priority date ( <i>day/month/year</i> ) <b>23.12.1998</b>
International Patent Classification (IPC) or national classification and IPC <sub>7</sub> <b>G 21 C 7/113</b>		
Applicant <b>ABB Atom AB et al</b>		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 3 sheets, including this cover sheet.  
  
☐ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of \_\_\_\_\_ sheets.

3. This report contains indications relating to the following items:

- I ☒ Basis of the report
- II ☐ Priority
- III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- IV ☐ Lack of unity of invention
- V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- VI ☐ Certain documents cited
- VII ☐ Certain defects in the international application
- VIII ☐ Certain observations on the international application

Date of submission of the demand  <b>10.07.2000</b>	Date of completion of this report  <b>21.11.2000</b>
Name and mailing address of the IPEA/SE Patent- och registreringsverket Box 5055 S-102 42 STOCKHOLM Facsimile No. 08-667 72 88	Authorized officer  <b>Tomas Lund/ELY</b> Telephone No. 08-782 25 00



# INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.

PCT/SE99/02268

## I. Basis of the report

### 1. With regard to the elements of the international application:\*

- ☒ the international application as originally filed
- ☐ the description:  
 pages \_\_\_\_\_, as originally filed  
 pages \_\_\_\_\_, filed with the demand  
 pages \_\_\_\_\_, filed with the letter of \_\_\_\_\_
- ☐ the claims:  
 pages \_\_\_\_\_, as originally filed  
 pages \_\_\_\_\_, as amended (together with any statement) under article 19  
 pages \_\_\_\_\_, filed with the demand  
 pages \_\_\_\_\_, filed with the letter of \_\_\_\_\_
- ☐ the drawings:  
 pages \_\_\_\_\_, as originally filed  
 pages \_\_\_\_\_, filed with the demand  
 pages \_\_\_\_\_, filed with the letter of \_\_\_\_\_
- ☐ the sequence listing part of the description:  
 pages \_\_\_\_\_, as originally filed  
 pages \_\_\_\_\_, filed with the demand  
 pages \_\_\_\_\_, filed with the letter of \_\_\_\_\_

### 2. With regard to the language, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language english which is:

- ☒ the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).
- ☒ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

### 3. With regard to any nucleotide and/or amino acid sequence disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

### 4. ☐ The amendments have resulted in the cancellation of:

- ☐ the description, pages \_\_\_\_\_
- ☐ the claims, Nos. \_\_\_\_\_
- ☐ the drawings, sheet/fig \_\_\_\_\_

### 5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2 (c)).\*\*

\* Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).

\*\* Any replacement sheet containing such amendments must be referred to under item I and annexed to this report.

## INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.

PCT/SE99/02268

**V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement****1. Statement**

Novelty (N)	Claims	<u>1-12</u>	YES
	Claims		NO
Inventive step (IS)	Claims	<u>1-12</u>	YES
	Claims		NO
Industrial applicability (IA)	Claims	<u>1-12</u>	YES
	Claims		NO

**2. Citations and explanations (Rule 70.7)**

The claimed invention relates to a control rod for boiling water reactors. The control rod comprises four absorber blades, which form an orthogonal cross with a cruciform centre. The capacity of the absorber blades to absorb neutrons is lower in the upper part of the control rod than in the lower part. At the upper part of the control rod the absorber blades comprise a radially inner part that lacks absorber material and a radially outer part that is provided with absorber material.

The object of the claimed invention is to achieve a control rod for a nuclear reactor which reduces the risk of fuel failure, especially on the fuel rods near the cruciform centre, when the control rod is extracted from the reactor core.

CH, A5, 665 046, cited in the International Search Report, discloses a control rod comprising four absorber blades, which form an orthogonal cross with a cruciform centre. The absorber blades comprise a radially inner part that lacks absorber material and a radially outer part that is provided with absorber material (see figure 2). However, the absorber material is evenly distributed on the longitudinal direction of the absorber blades, whereas in the claimed invention the quantity of absorber material is lower in the upper part of the absorber blades of the control rod.

Therefore, the claimed invention is novel, it is not regarded obvious to a person skilled in the art and there will be no doubts about its usefulness. Therefore, the stipulated criteria regarding novelty, inventive step and industrial applicability under PCT Article 33 (1) are fulfilled for the claimed invention.

The demand must be filed directly with the competent International Preliminary Examining Authority or, if two or more Authorities are competent, with the one chosen by the applicant. The full name or two-letter code of that Authority may be indicated by the applicant on the line below:

IPEA/ SE

# PCT

## CHAPTER II

### DEMAND

under Article 31 of the Patent Cooperation Treaty:

The undersigned requests that the international application specified below be the subject of international preliminary examination according to the Patent Cooperation Treaty and hereby elects all eligible States (except where otherwise indicated).

For International Preliminary Examining Authority use only

Identification of IPEA		Date of receipt of DEMAND	
<b>Box No. I IDENTIFICATION OF THE INTERNATIONAL APPLICATION</b>			Applicant's or agent's file reference KN 8569 WO
International application No. PCT/SE99/02268	International filing date (day/month/year) 06 December 1999 (06.12.99)	(Earliest) Priority date (day/month/year) 23 December 1998(23.12.98)	
Title of invention Control rod			
<b>Box No. II APPLICANT(S)</b>			
Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)  ABB Atom AB SE-721 63 Västerås Sweden		Telephone No.: +46 21 34 70 00	
		Facsimile No.: +46 21 18 94 71	
		Teleprinter No.:	
State (that is, country) of nationality: SE		State (that is, country) of residence: SE	
Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)  BERNANDER, Örjan Eldstensgatan 6 SE-723 53 Västerås Sweden			
State (that is, country) of nationality: SE		State (that is, country) of residence: SE	
Name and address: (Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)  HELMERSSON, Sture Strandvägen 2 SE-730 40 Kolbäck Sweden			
State (that is, country) of nationality: SE		State (that is, country) of residence: SE	
<input type="checkbox"/> Further applicants are indicated on a continuation sheet.			

**Box No. III AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE**The following person is ☒ agent ☐ common representativeand ☒ has been appointed earlier and represents the applicant(s) also for international preliminary examination.☐ is hereby appointed and any earlier appointment of (an) agent(s)/common representative is hereby revoked.☐ is hereby appointed, specifically for the procedure before the International Preliminary Examining Authority, in addition to the agent(s)/common representative appointed earlier.Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*LARSSON,Håkan; TARKPEA, Pia  
ABB AB  
Patent  
SE-721 78 Västerås  
Sweden

Telephone No.:

+46 21 32 30 00

Facsimile No.:

+46 21 18 13 86

Teleprinter No.:

☐ Address for correspondence: Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.**Box No. IV BASIS FOR INTERNATIONAL PRELIMINARY EXAMINATION****Statement concerning amendments:\***

1. The applicant wishes the international preliminary examination to start on the basis of:

☒ the international application as originally filedthe description ☐ as originally filed  
☐ as amended under Article 34the claims ☐ as originally filed  
☐ as amended under Article 19 (together with any accompanying statement)  
☐ as amended under Article 34the drawings ☐ as originally filed  
☐ as amended under Article 342. ☐ The applicant wishes any amendment to the claims under Article 19 to be considered as reversed.3. ☐ The applicant wishes the start of the international preliminary examination to be postponed until the expiration of 20 months from the priority date unless the International Preliminary Examining Authority receives a copy of any amendments made under Article 19 or a notice from the applicant that he does not wish to make such amendments (Rule 69.1(d)). *(This check-box may be marked only where the time limit under Article 19 has not yet expired.)*

\* Where no check-box is marked, international preliminary examination will start on the basis of the international application as originally filed or, where a copy of amendments to the claims under Article 19 and/or amendments of the international application under Article 34 are received by the International Preliminary Examining Authority before it has begun to draw up a written opinion or the international preliminary examination report, as so amended.

Language for the purposes of international preliminary examination: English☐ which is the language in which the international application was filed.☒ which is the language of a translation furnished for the purposes of international search.☐ which is the language of publication of the international application.☐ which is the language of the translation (to be) furnished for the purposes of international preliminary examination.**Box No. V ELECTION OF STATES**The applicant hereby elects all eligible States *(that is, all States which have been designated and which are bound by Chapter II of the PCT)*

excluding the following States which the applicant wishes not to elect:

**Box No. VI CHECK LIST**

The demand is accompanied by the following elements, in the language referred to in Box No. IV, for the purposes of international preliminary examination:

- |  |   |        |
|--|---|--------|
| 1. translation of international application                              | : | sheets |
| 2. amendments under Article 34   | : | sheets |
| 3. copy (or, where required, translation) of amendments under Article 19 | : | sheets |
| 4. copy (or, where required, translation) of statement under Article 19  | : | sheets |
| 5. letter  | : | sheets |
| 6. other ( <i>specify</i> )  | : | sheets |

For International Preliminary  
Examining Authority use only

received                      not received

<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>

The demand is also accompanied by the item(s) marked below:

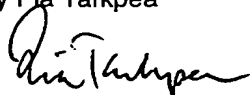
- |  |   |
|--|---|
| 1. <input checked="" type="checkbox"/> fee calculation sheet   | 4. <input type="checkbox"/> statement explaining lack of signature                                  |
| 2. <input type="checkbox"/> separate signed power of attorney  | 5. <input type="checkbox"/> nucleotide and or amino acid sequence listing in computer readable form |
| 3. <input checked="" type="checkbox"/> copy of general power of attorney;<br>reference number, if any: GF3360/99 | 6. <input type="checkbox"/> other ( <i>specify</i> ):   |

**Box No. VII SIGNATURE OF APPLICANT, AGENT OR COMMON REPRESENTATIVE**

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the demand).

Västerås, Sweden, 07.07.2000

ABB Atom AB  
by Pia Tarkpea



For International Preliminary Examining Authority use only

1. Date of actual receipt of DEMAND:

2. Adjusted date of receipt of demand due  
to CORRECTIONS under Rule 60.1(b):

3. ☐ The date of receipt of the demand is AFTER the expiration of 19 months from the priority date and item 4 or 5, below, does not apply.

☐ The applicant has been informed accordingly.

4. ☐ The date of receipt of the demand is WITHIN the period of 19 months from the priority date as extended by virtue of Rule 80.5.

5. ☐ Although the date of receipt of the demand is after the expiration of 19 months from the priority date, the delay in arrival is EXCUSED pursuant to Rule 82.

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Demand received from IPEA on:

## PCT

## FEE CALCULATION SHEET

Annex to the Demand for international preliminary examination

International application No. <b>PCT/SE99/02268</b>	For International Preliminary Examining Authority use only	
Applicant's or agent's file reference <b>KN 8569 WO</b>	Date stamp of the IPEA	
Applicant <b>ABB Atom AB et al</b>		
<b>Calculation of prescribed fees</b>		
1. Preliminary examination fee .....	<div style="border: 1px solid black; display: inline-block; padding: 2px 10px;">4200</div> <div style="border: 1px solid black; display: inline-block; padding: 2px 5px; margin-left: 5px;">P</div>	
2. Handling fee <i>(Applicants from certain States are entitled to a reduction of 75% of the handling fee. Where the applicant is (or all applicants are) so entitled, the amount to be entered at H is 25% of the handling fee.)</i> .....	<div style="border: 1px solid black; display: inline-block; padding: 2px 10px;">1270</div> <div style="border: 1px solid black; display: inline-block; padding: 2px 5px; margin-left: 5px;">H</div>	
3. Total of prescribed fees Add the amounts entered at P and H and enter total in the TOTAL box .....	<div style="border: 1px solid black; display: inline-block; padding: 2px 10px;">5470</div>	
	<div style="border: 1px solid black; display: inline-block; padding: 2px 10px;">TOTAL</div>	
<b>Mode of Payment</b>		
<input type="checkbox"/> authorization to charge deposit account with the IPEA (see below)	<input type="checkbox"/> cash	
<input type="checkbox"/> cheque	<input type="checkbox"/> revenue stamps	
<input checked="" type="checkbox"/> postal money order	<input type="checkbox"/> coupons	
<input type="checkbox"/> bank draft	<input type="checkbox"/> other (specify):	
<b>Deposit Account Authorization</b> <i>(this mode of payment may not be available at all IPEAs)</i>		
The IPEA/ <u>SE</u> <input type="checkbox"/> is hereby authorized to charge the total fees indicated above to my deposit account.		
<input type="checkbox"/> <i>(this check-box may be marked only if the conditions for deposit accounts of the IPEA so permit)</i> is hereby authorized to charge any deficiency or credit any overpayment in the total fees indicated above to my deposit account.		
Deposit Account Number	Date (day/month/year)	Signature

**PCT (ANNEX - FEE CALCULATION SHEET)**

KN8569WO

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(This sheet is not part of and does not count as a sheet of the international application)

0	For receiving Office use only	
0-1	International Application No.	
0-2	Date stamp of the receiving Office	
0-4	Form - PCT/RO/101 (Annex) PCT Fee Calculation Sheet	
0-4-1	Prepared using	PCT-EASY Version 2.90 (updated 15.10.1999)
0-9	Applicant's or agent's file reference	KN8569WO
2	Applicant	ABB AB, et al.
12	Calculation of prescribed fees	fee amount/multiplier      total amounts (SEK)
12-1	Transmittal fee      T	⇒      1 000
12-2	Search fee      S	⇒      8 510
12-3	International fee Basic fee (first 30 sheets)      b1	3 500
12-4	Remaining sheets      0	
12-5	Additional amount      (X)	80
12-6	Total additional amount      b2	0
12-7	b1 + b2 =      B	3 500
12-8	Designation fees Number of designations contained in international application      3	
12-9	Number of designation fees payable (maximum 10)      3	
12-10	Amount of designation fee      (X)	800
12-11	Total designation fees      D	2 400
12-12	PCT-EASY fee reduction      R	-1 080
12-13	Total International fee (B+D-R)      I	⇒      4 820
12-14	Fee for priority document Number of priority documents requested      1	
12-15	Fee per document      (X)	0
12-16	Total priority document fee      P	⇒      0
12-17	TOTAL FEES PAYABLE (T+S+I+P)	⇒      14 330
12-19	Mode of payment	postal money order

**VALIDATION LOG AND REMARKS**

13-2-1	Validation messages Request	Green? A translation of the international application into English will have to be prepared under the responsibility of the ISA selected.
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**PCT (ANNEX - FEE CALCULATION SHEET)**

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		<b>Green?</b> Please note that the entire request (including the title of invention) must be in English
13-2-2	Validation messages States	<b>Green?</b> More designations could be made. Please verify.
13-2-3	Validation messages Names	<b>Yellow</b> Applicant 1.:Street address missing



PCT

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**PCT-EASY INFORMATION SHEET**

(For applicant use only, DO NOT submit this sheet with the international application)

**VALIDATION LOG**

	<b>Request</b>
Green?	A translation of the international application into English will have to be prepared under the responsibility of the ISA selected.
Green?	Please note that the entire request (including the title of invention) must be in English
	<b>States</b>
Green?	More designations could be made. Please verify.
	<b>Names</b>
Yellow	Applicant 1.:Street address missing

Before submitting the International Application, please carefully verify that:

- the information contained on printed Request form is correct;
- Box IX of the Request form has been signed;
- all elements of the International application as indicated in Box VIII of the Request form have been attached; and,
- the diskette containing the PCT-EASY zip file of the International Application has been enclosed and has been clearly labeled "PCT-EASY", with the applicant's or agent's file reference, and the first applicant's name.

**ATTENTION**

DO NOT modify any indications on the Request form printout. The attached PCT-EASY application has been locked. If an error or an omission is discovered at this time, you must copy the submitted application as a template and make the change or correction in a new application (using the submitted application as a template). You may create such a template by copying the submitted application from the "Stored Forms" folder to the "New PCT Forms" folder. Open the new (.OWO) file created in the "New PCT Forms" folder, correct the errors and proceed with the submission process again.

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**PCT REQUEST**

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0	For receiving Office use only	
0-1	International Application No.	PCT/SE 99/02268
0-2	International Filing Date	1999-12-06
0-3	Name of receiving Office and "PCT International Application"	<b>The Swedish Patent Office</b> <b>PCT International Application</b>
0-4	Form - PCT/RO/101 PCT Request Prepared using	PCT-EASY Version 2.90 (updated 15.10.1999)
0-5	<b>Petition</b> The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty	
0-6	Receiving Office (specified by the applicant)	Swedish Patent Office (RO/SE)
0-7	Applicant's or agent's file reference	KN8569WO
I	Title of Invention	CONTROL ROD
II	<b>Applicant</b>	
II-1	This person is:	applicant only
II-2	Applicant for	all designated States except US
II-4	Name	ABB AB
II-5	Address:	S-Västerås 721 83 Sweden
II-6	State of nationality	SE
II-7	State of residence	SE
II-8	Telephone No.	+46 21 32 50 00
II-9	Facsimile No.	+46 21 13 41 12
III-1	<b>Applicant and/or inventor</b>	
III-1-1	This person is:	applicant and inventor
III-1-2	Applicant for	US only
III-1-4	Name (LAST, First)	BERNANDER, Örjan
III-1-5	Address:	Eldstensgatan 6 S-723 53 VÄSTERÅS Sweden
III-1-6	State of nationality	SE
III-1-7	State of residence	SE

06-12-1999

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## PCT REQUEST

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<b>III-2</b>	<b>Applicant and/ or inventor</b>	
III-2-1	This person is:	<b>applicant and inventor</b>
III-2-2	Applicant for	<b>US only</b>
III-2-4	Name (LAST, First)	<b>HELMERSSON, Sture</b>
III-2-5	Address:	<b>Strandvägen 2 S-730 40 Kolbäck Sweden</b>
III-2-6	State of nationality	<b>SE</b>
III-2-7	State of residence	<b>SE</b>
<b>IV-1</b>	<b>Agent or common representative; or address for correspondence</b>	
	The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as:	<b>agent</b>
IV-1-1	Name	<b>ABB AB</b>
IV-1-2	Address:	<b>Patent Gideonsbergsgatan 2 S-721 78 Västerås Sweden</b>
IV-1-3	Telephone No.	<b>+46 21 32 30 00</b>
IV-1-4	Facsimile No.	<b>+46 21 18 13 86</b>
<b>IV-2</b>	<b>Additional agent(s)</b>	<b>additional agent(s) with same address as first named agent</b>
IV-2-1	Name(s)	<b>LARSSON, Håkan; TARKPEA, Pia</b>
<b>V.</b>	<b>Designation of States</b>	
V-1	Regional Patent (other kinds of protection or treatment, if any, are specified between parentheses after the designation(s) concerned)	<b>EP: AT BE CH&amp;LI CY DE DK ES FI FR GB GR IE IT LU MC NL PT SE and any other State which is a Contracting State of the European Patent Convention and of the PCT</b>
V-2	National Patent (other kinds of protection or treatment, if any, are specified between parentheses after the designation(s) concerned)	<b>JP US</b>
<b>V-5</b>	<b>Precautionary Designation Statement</b> In addition to the designations made under items V-1, V-2 and V-3, the applicant also makes under Rule 4.9(b) all designations which would be permitted under the PCT except any designation(s) of the State(s) indicated under item V-6 below. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit.	
<b>V-6</b>	<b>Exclusion(s) from precautionary designations</b>	<b>NONE</b>

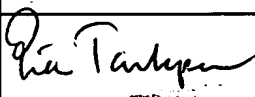
06-12-1999

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## PCT REQUEST

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VI-1	Priority claim of earlier national application		
VI-1-1	Filing date	23 December 1998 (23.12.1998)	
VI-1-2	Number	9804518-0	
VI-1-3	Country	SE	
VI-2	Priority document request The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) identified above as item(s):	VI-1	
VII-1	International Searching Authority Chosen	Swedish Patent Office (ISA/SE)	
VII-2	Request to use results of earlier search; reference to that search		
VII-2-1	Date	23 December 1998 (23.12.1998)	
VII-2-2	Number	98/01565	
VII-2-3	Country (or regional Office)	SE	
VIII	Check list	number of sheets	electronic file(s) attached
VIII-1	Request	4 ✓	-
VIII-2	Description	10 ✓	-
VIII-3	Claims	2 ✓	-
VIII-4	Abstract	1 ✓	kn_8569_wo_abs.txt
VIII-5	Drawings	5 ✓	-
VIII-7	TOTAL	22	
	Accompanying items	paper document(s) attached	electronic file(s) attached
VIII-8	Fee calculation sheet	✓	-
VIII-10	Copy of general power of attorney	reference no. GF 3562/99	-
VIII-13	Translation of international application into:	English	
VIII-16	PCT-EASY diskette	-	diskette
VIII-17	Other (specified):	Copy of substitute power of attorney	-
VIII-17	Other (specified):	Copy of ITS-Report	-
VIII-18	Figure of the drawings which should accompany the abstract	2a	
VIII-19	Language of filing of the international application	Swedish	
IX-1	Signature of applicant or agent		
IX-1-1	Name	ABB AB	
IX-1-2	Name of signatory	Pia Tarkpea	
IX-1-3	Capacity	Patent attorney	

## FOR RECEIVING OFFICE USE ONLY

10-1	Date of actual receipt of the purported international application	1999-12-06
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PCT REQUEST

KN8569WO

Original (for SUBMISSION) - printed on 03.12.1999 11:14:32 AM

10-2	Drawings:	
10-2-1	Rec ived	X
10-2-2	Not received	
10-3	Corrected date of actual receipt due to later but timely received papers or drawings completing the purported International application	
10-4	Date of timely receipt of the required corrections under PCT Article 11(2)	
10-5	International Searching Authority	ISA/SE
10-6	Transmittal of search copy delayed until search fee is paid	

FOR INTERNATIONAL BUREAU USE ONLY

11-1	Date of receipt of the record copy by the International Bureau	09 FEBRUARY 2000	09 FEB 2000
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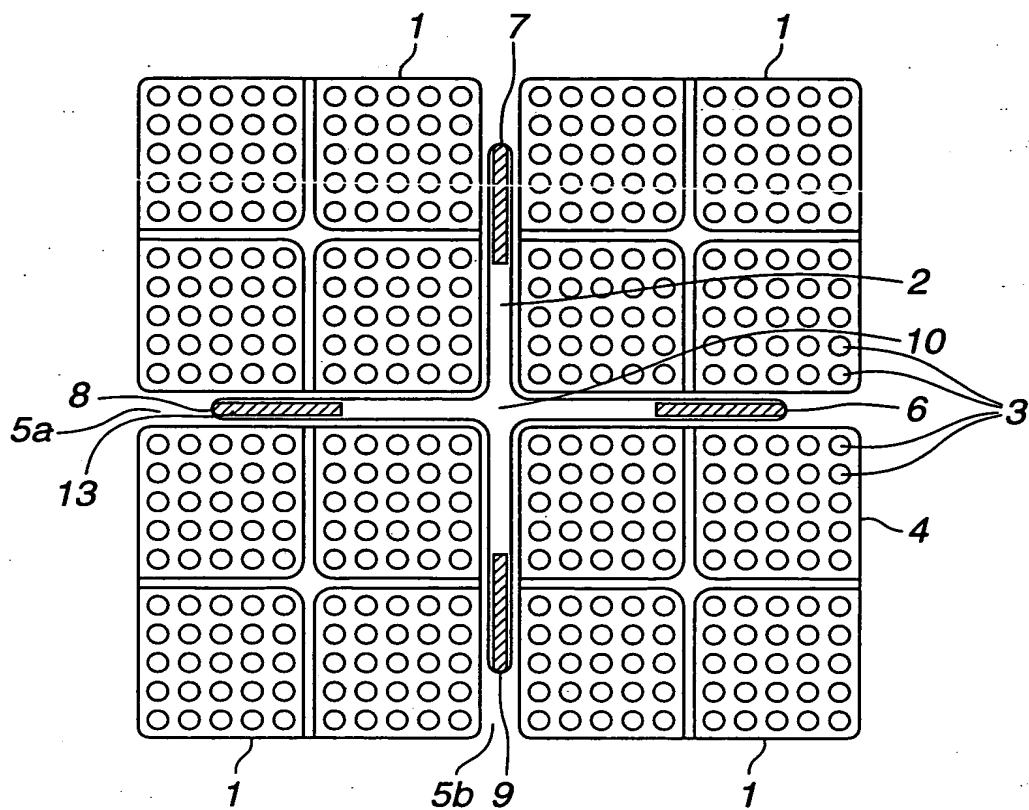
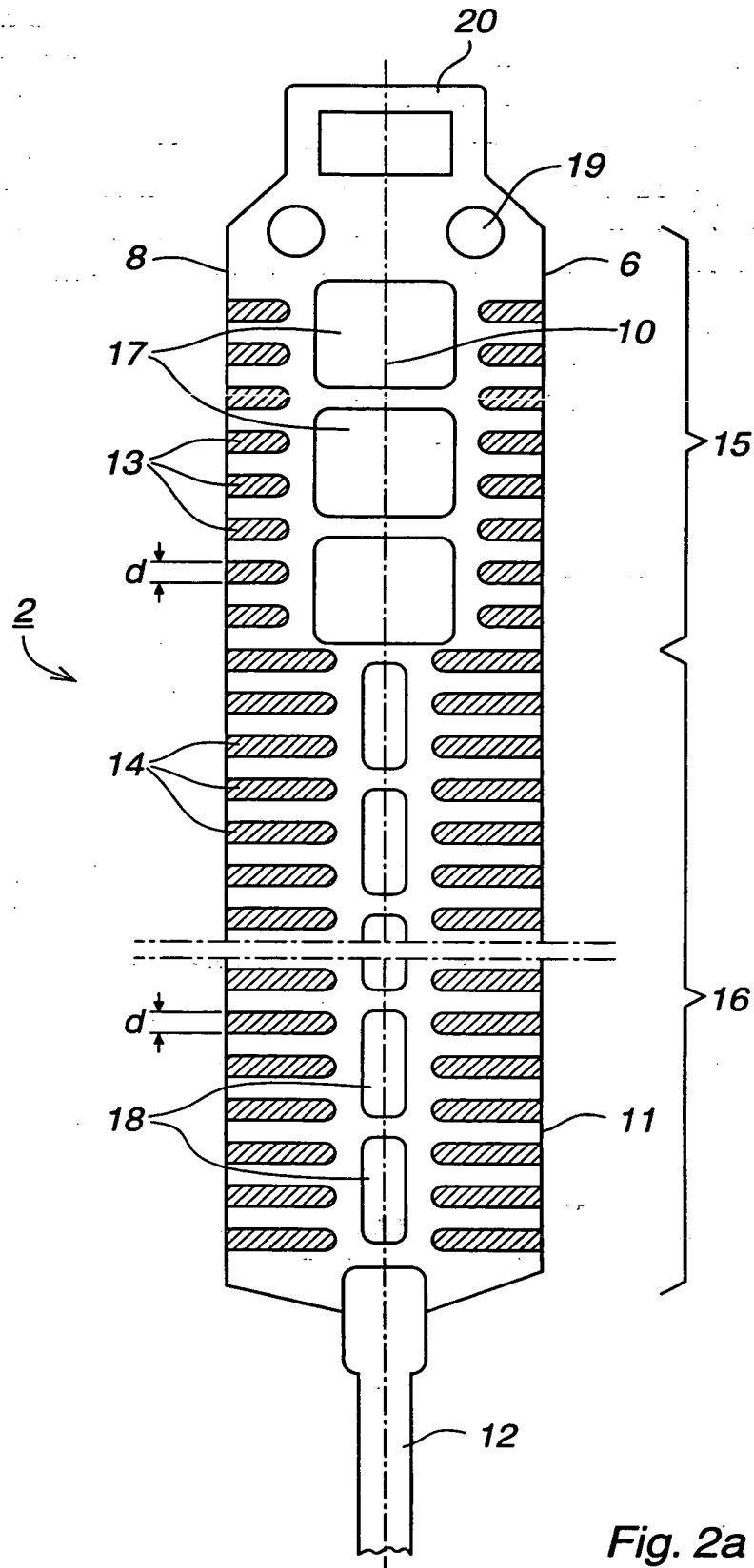


Fig. 1

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**Fig. 2a**

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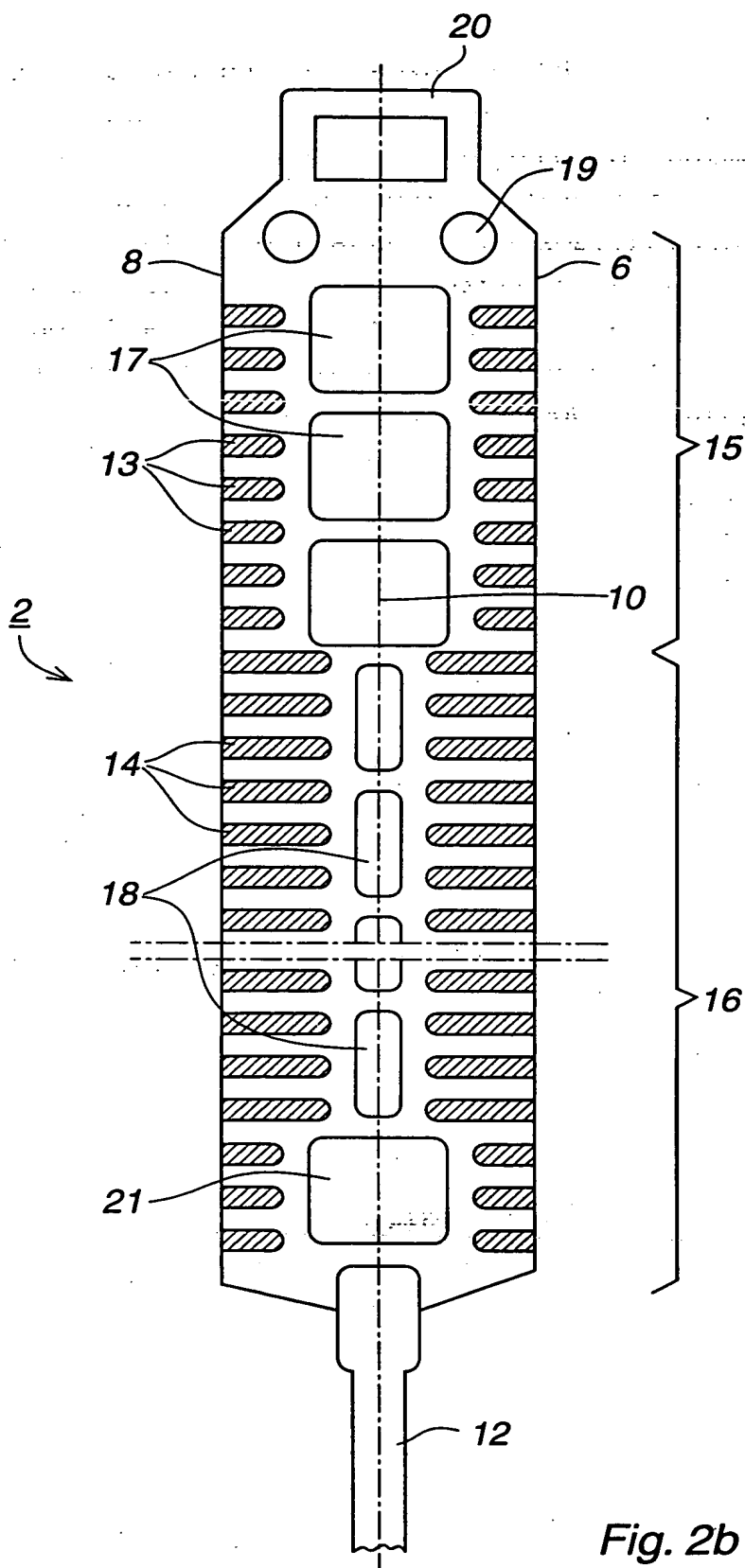
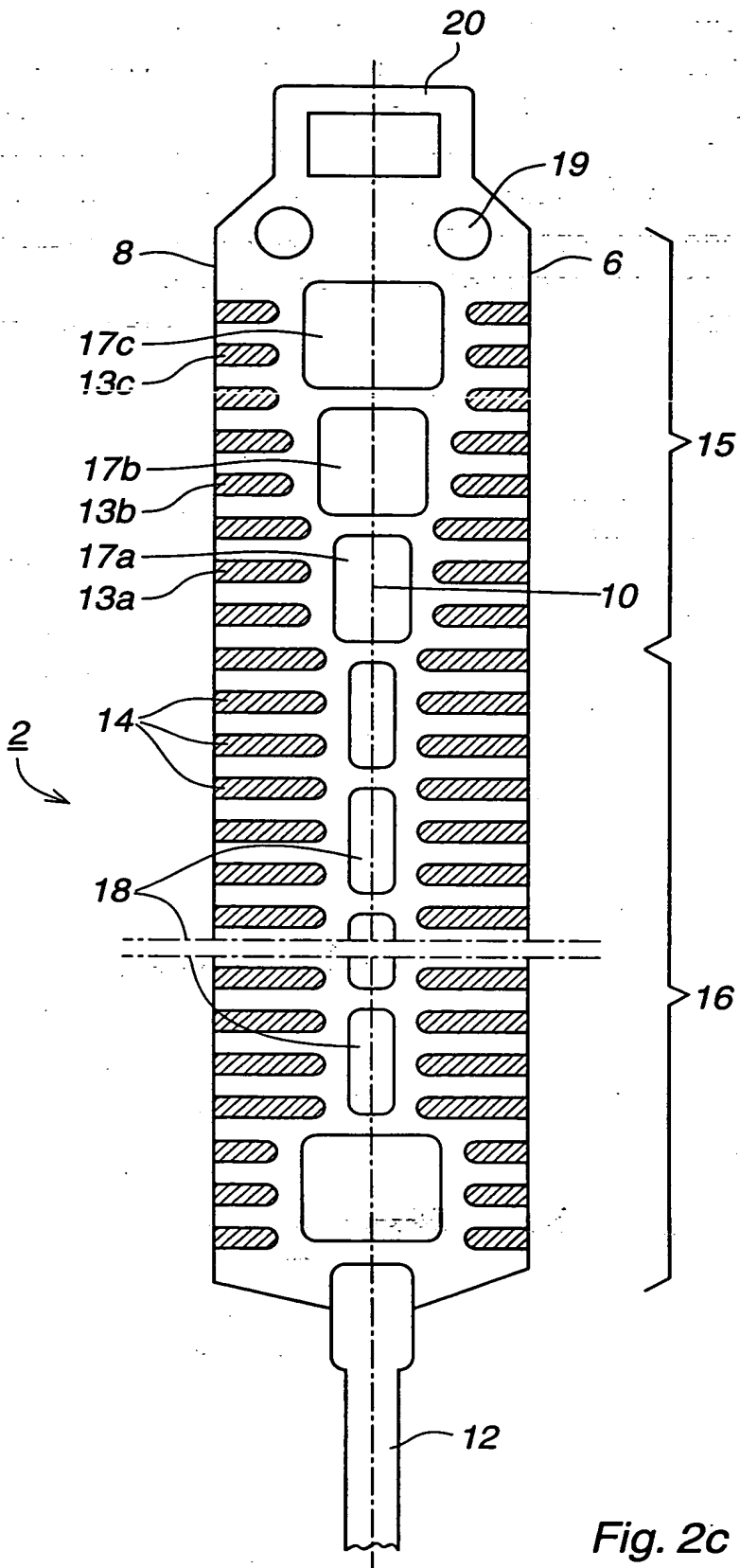


Fig. 2b



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**Fig. 2c**

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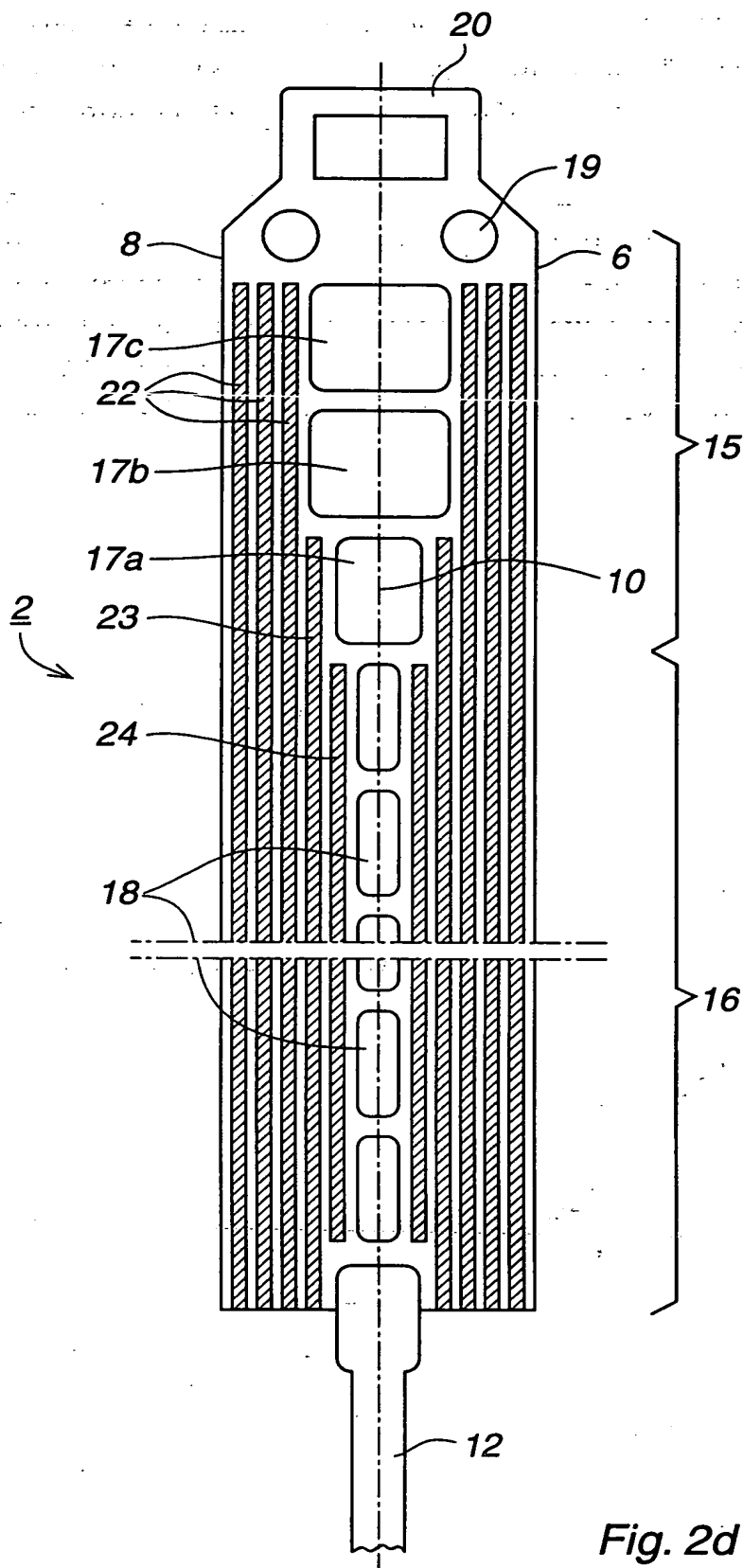


Fig. 2d

## STYRSTAV

## TEKNISKT OMRÅDE

- 5 Föreliggande uppfinning avser en styrstav för en kokarvatten-reaktor innefattande fyra absorbatorblad som bildar ett rätvinkligt kors. Absorbatorbladen innehåller i längdriktningen fördelat absorbatormaterial, varvid ett medelvärde av mängden absorbatormaterial per längdenhet av styrstaven är
- 10 mindre i styrstavens övre del än i dess nedre del.

## TEKNIKENS STÅNDPUNKT

- En härd i en kokarvattenreaktor innehåller normalt flera
- 15 hundra bränslepatroner. Dessa är anordnade vertikalt i härden och har ett åtminstone i huvudsak kvadratisk tvärsnitt. Varje bränslepatron innefattar ett knippe av bränslestavar. I kokarvattenreaktorer används ofta bränsleknippen som innehåller 8x8, 9x9 eller 10x10 bränslestavar. Ett
- 20 bränsleknippe omsluts av ett höljerör. Höljeröret är öppet i båda ändar så att reaktorns kylmedel kan strömma genom bränsleknippet. Härden är nedsänkt i vatten vilket tjänstgör både som kylmedel och som neutronmoderator. Varje bränslestav innehåller ett stort antal bränslekutsar staplade ovanpå
- 25 varandra i ett kapslingsrör.

- En kärnreaktor innefattar också ett flertal styrsstavar vars primära uppgift är att starta, reglera och stänga av effektgenereringen genom att de förs in i och ut ur reaktor-
- 30 härden. I kokarvattenreaktorn förs styrsstavarna in i härden underifrån. Med hjälp av ett drivdon kan styrsstaven manövreras i olika lägen mellan helt utdragen och helt införd i härden. Vissa av styrsstavarna är under drift utdragna ur härden, medan andra är införda till olika nivåer. Dessa
- 35 nivåer varierar under reaktorns driftcykel. I kokarvattenreaktorn är styrsstavarna uppbyggda av fyra vertikalt anordnade avlånga absorbatorblad, som tillsammans bildar ett rätvinkligt kors. Absorbatorbladen är i allmänhet av rostfritt stål och försedda med ett stort antal borrar

hål eller rör fyllda med ett neutronabsorberande material, t ex borkarbid ( $B_4C$ ) eller hafnium. Absorbatormaterialet är vanligtvis likformigt fördelat i både axiell och radiell led i absorbatorbladen. Styrstavarnas aktiva längd, d v s längden av den del av styrstaven som innehåller absorbatormaterialet, motsvarar reaktorhårdens aktiva höjd när styrstavarna är fullt inskjutna i hårdens.

Bränslepatronerna är anordnade i ett regelbundet gitter, där varje bränslepatron ingår i två mot varandra vinkelräta rader av bränslepatroner. Styrstavarna är normalt anordnade med vart och ett av sina absorbatorblad mellan två i samma rad belägna bränslepatroner, så att varje styrstav tillsammans med fyra omkring dess blad anordnade bränslepatroner bildar en enhet.

Styrstavarna i reaktorn är vanligen uppdelade i två grupper med olika uppgifter. Den ena gruppen av styrstavar är under normal drift helt utdragna ur hårdens och används endast för att stoppa och starta reaktorn. Den andra gruppen används för reglering av reaktoreffekten och för utbränningskompensation under normal reaktordrift. Styrstavarna i den andra gruppen kommer i fortsättningen att benämnas reglerstavar. Dessa reglerstavar utgör vanligen mindre än 10% av alla styrstavar. I början av en driftcykel är reglerstavarna inskjutna. Med en driftcykel avses tiden mellan två bränslebyten. För att kompensera för bränslets utbränning dras reglerstavarna successivt ut under driftcykeln. Ändringen av reglerstavarnas lägen sker med vissa tidsintervall, t ex en gång per vecka. Ändringen kan t ex bestå i att reglerstavarna dras ut ca 8% av sin längd.

Idag används konventionella styrstavar, med absorbatormaterialet likformigt fördelat i absorbatorbladen, i båda styrstavsgруппerna. Under den tid reglerstavarna är inskjutna skyddas de bränslekutsar som befinner sig intill absorbatorbladen från utbränning av fissilt material. Detta leder till att vid varje tillfälle som reglerstaven dras ut en bit friläggs bränslekutsar som innehåller höga halter av fissilt

material, varvid en avsevärd effekthöjning äger rum i dessa bränslekutsar. Denna lokala effekthöjning sker mycket snabbt. Sådana påkänningar kan i vissa fall orsaka bränsleskador, s k PCI-skador (PCI = pellet-clad interaction), på kapslingsröret som omger bränslekutsarna. De bränslestavar som befinner sig närmast reglerstavens korscentrum är särskilt utsatta för sådana påkänningar och löper därmed störst risk för bränsleskador. Orsaken till detta är att dessa bränslestavar skyddas mot utbränning av fissilt material av två absorbatorblad.

Från den amerikanska patentansökan nr 367 099 är en styrstav känd som i sin övre del är anordnad med en mindre andel absorbatormaterial per längdenhet än styrstaven i övrigt. På så vis hinner en del av det fissila materialet brännas ut under den tid som styrstaven är helt inskjuten i härden och effektökningen blir inte lika stor när reglerstaven dras ut. En minskad effektökning när reglerstaven dras ut åstadkoms genom att ett stort antal borrarade kanaler anordnas vinkelrätt mot styrstavens längdriktning och fylls med ett neutronabsorberande material, varvid kanalerna i styrstavens övre del har en relativt mindre radie, varvid respektive kanals längd är väsentligt större än dess radie, medan de övriga kanalerna har en relativt större radie.

En nackdel med denna styrstav är att den erhållna minskningen av effektökningen när styrstaven dras ut inte är tillräckligt stor för att eliminera risken för bränsleskador på de mest utsatta bränslestavarna, d v s bränslestavarna som befinner sig närmast styrstavens korscentrum.

En annan nackdel är att livslängden blir kortare för ovan nämnda styrstav än för konventionella styrsstavar. Livslängden för absorbatormaterialet, och därmed styrstavens livslängd, beror av mängden absorbatormaterial per ytenhet. För en cylinderformad kanal vars längd är väsentligt större än dess radie gäller att livslängden för absorbatormaterialet huvudsakligen påverkas av dess radie. En minskning av

kanalernas diameter leder till motsvarande minskning av livslängden hos styrstaven.

- Från den amerikanska patentansökan nr 659 436 är det känt att
- 5 anordna mindre mängd absorbatormaterial i den del av absorbatorbladen som sträcker sig utefter de närmast korscentrum belägna bränslestavarna. Bladen är i sin yttre del försedda med ett stort antal, med absorbatormaterial fyllda, kanaler som sträcker sig vinkelrätt mot styrstavens
- 10 längdriktning. I en utföringsform saknar den del av absorbatorbladen som är belägen innanför de fyllda kanalerna absorbatormaterial. Styrsstaven är försedd med ursparingar, vilka sträcker sig över den närmast korscentrum belägna bränslestaven. Dessa ursparingar är moderatorfyllda så att
- 15 konsumtionen av fissilt material i närbelägna bränslestavar ökar. Genom att anordna absorbatormaterialet på detta sätt möjliggörs att längden på en driftscykel för en reaktor kan förlängas avsevärt.
- 20 Nackdelen med att använda en sådan styrsstav som reglerstav är att risken för bränsleskador visserligen har minskats för de mest utsatta bränslestavarna, d v s de närmast korscentrum, men risken för bränsleskador på övriga bränslestavar är oförändrad jämfört med risken för bränsleskador vid
- 25 användande av konventionella styrsstavar.

#### SAMMANFATTNING AV UPPFINNINGEN

- Ändamålet med uppfinningen är att åstadkomma en styrsstav för
- 30 en kärnreaktor som ger en minskad risk för bränsleskador när den från ett infört läge under en längre tid i successiva steg dras ut ur reaktorhärden.

- Vad som kännetecknar en styrsstav enligt uppfinningen framgår
- 35 av bifogade patentkrav.

En styrsstav enligt uppfinningen har absorbatorblad, som bildar ett rätvinkligt kors med ett centralt korscentrum, och vars förmåga att absorbera neutroner varierar både axiellt

och radiellt. Absorbatorbladens förmåga att absorbera neutroner är lägre i dess övre del än i dess nedre del. I absorbatorbladens övre del är neutronabsorptionsförmågan högre i dess yttre del än i dess inre del som gränsar till korscentrumet. Styrstaven enligt uppfinningen leder till att effektsänkningen för bränslekutsar belägna intill den övre delen av styrstaven blir mindre, relativt bränslekutsar som ej kontrolleras med avseende på klyvningshastighet med hjälp av styrstavar. Speciellt de bränslekutsar som är belägna närmast styrstavens korscentrum får en mindre effektsänkning än de bränslekutar som ej kontrolleras med hjälp av styrstavar. När styrstaven dras ut en bit, och bränslekutsarna som skyddats av styrstavens övre del friläggs, blir effektökningen i dessa bränslekutsar mindre än för tidigare kända styrstavar, p g a att bränslekutsarna redan är utbrända till en viss del.

En fördel med en styrstav enligt uppfinningen är att risken för bränsleskador på kapslingsröret i samband med att styrstaven dras ut minskas. En annan fördel är att utnyttjandet av bränslet blir effektivare. Ytterligare en fördel är att längre livslängd för styrstavarna möjliggörs.

I en styrstav enligt uppfinningen innefattar vart och ett av absorbatorbladen en övre och en nedre del, varvid medelvärdet av innehållet av absorbatormaterial per längdenhet av styrstaven är mindre i styrstavens övre del än i dess nedre del. Den övre delen innefattar en yttre del försedd med absorbatormaterial och en inre del som saknar absorbatormaterial och som är anordnad radiellt innanför den yttre delen.

För att uppnå fördelarna med uppfinningen bör åtminstone något parti av nämnda inre del utgöra minst en fjärdedel av absorbatorbladets bredd i radiell led. I en speciellt fördelaktig utföringsform bör åtminstone något parti av nämnda inre del utgöra minst en tredjedel av absorbatorbladets bredd i radiell ledd. Arean, i ett snitt tvärs styrstavens längdriktning, av nämnda inre del bör vara

minst 25% av den övre delens area. I en speciellt fördelaktig utföringsform bör arean, i ett snitt tvärs styrestavens längdriktning, av nämnda inre del vara minst 30% av den övre delens area. Den övre delens längd bör inte överstiga en tredjedel av absorlatorbladets totala längd.

I en föredragen utföringsform av uppfinningen anordnas ursparingar i form av genomgående hål i de inre centrala delarna av styrestavens övre del. Detta medför att mer neutronmoderator tillförs styrestavens övre centrala del vilket ytterligare ökar utbränningen av fissilt material i bränslestavarna som är anordnade närmast styrestavens korscentrum.

#### 15 FIGURBESKRIVNING

Figur 1 visar i ett horisontellt snitt en liten del av en reaktorhård för en kokarvattenreaktor, närmare bestämt ett tvärsnitt genom fyra bränslepatroner med en centralt mellan dessa placerad styrestav.

Figur 2a - 2d visar i vertikala snitt olika utföringsformer av en styrestav enligt uppfinningen.

#### 25 BESKRIVNING AV UTFÖRINGSFORMER

Figur 1 visar ett horisontellt snitt genom fyra bränslepatroner 1 med en tillhörande styrestav 2 placerad mellan dessa. Snittet är lagt genom styrestavens 2 övre del. Varje bränslepatron 1 innefattar 10x10 bränslestavar 3. Bränslestavarna 3 är inneslutna i ett höljerör 4 med ett kvadratisk tvärsnitt. Varje bränslestav 3 innefattar ett antal bränslekutsar av urandioxid staplade på varandra och inkapslade i ett kapslingsrör. Utrymmena mellan bränslestavarna 3 i bränslepatronen 1 genomströmmas av vatten som utgör både kylmedel och moderator. Mellan bränslepatronerna 1 bildas spalter 5a och 5b vilka genomströmmas av vatten. Styrestaven 2 är införd i spalterna 5a och 5b och har fyra



absorbatorblad 6,7,8,9 som bildar ett rätvinkligt kors.  
Styrstavens korscentrum är betecknat 10.

Figur 2a visar ett vertikalt snitt genom en styrstav 2 enligt  
5 uppfinningen. Styrstaven 2 är i huvudsak utförd av rostfritt  
stål och innefattar en absorbator del 11, som är uppburen av  
en vertikal kopplingsstång 12. Styrstaven 2 innefattar en  
övre del 15 och en nedre del 16. Den övre delens längd utgör  
högst en tredjedel av absorbator delens 11 totala längd. Två  
10 av de fyra absorbatorbladen 6 och 8 är synliga i figur 2a.  
Vart och ett av absorbatorbladen 6,8 är försett med ett stort  
antal borrarade kanaler 13,14 som sträcker sig vinkelrätt mot  
styrstavens 2 längdriktning, från absorbatorbladets 6,8 yttre  
kant och in mot korscentrum 10. Vardera kanalen 13, 14 är  
15 fylld med ett absorbator material, t ex naturlig eller anrikad  
borkarbid och/eller metalliskt hafnium, gadolinium eller  
erbio, och är utåt hermetiskt tillsluten genom t ex  
svetsning. Dessa kanaler benämns i fortsättningen  
absorbator kanaler. Absorbator kanalerna 13 som är anordnade i  
20 absorbatorbladens övre del 15 är väsentligt kortare än  
absorbator kanalerna 14 som är anordnade i absorbatorbladens  
nedre del 16. Absorbator kanalerna 13 är anordnade i en yttre  
del, anordnad radiellt utanför en inre del, av  
absorbatorbladets övre del 15. Absorbator kanalerna 13 har  
25 vardera en längd som är åtminstone 30% kortare än längden hos  
en av absorbator kanalerna 14 i den nedre delen 16.

Absorbator kanalerna 13,14, i den övre delen 15 respektive i  
den nedre delen 16 av absorbatorbladen, är företrädesvis  
30 cirkulär cylindriska till sin form och har alla samma diameter  
d. För att erhålla maximal livslängd bör absorbator kanalernas  
13,14 diameter d vara den största möjliga med hänsyn tagen  
till absorbatorbladens godstjocklek. Livslängden för  
absorbator materialet beror av mängden absorbator material per  
35 ytenhet, beskrivet under teknikens ståndpunkt. Däremot ger en  
halvering av absorbator kanalens längd med en bibehållen  
diameter d endast en marginell påverkan på livslängden. På så  
sätt bibehålls styrstavens livslängd trots att andelen  
absorbator material minskas i dess övre del.

Den del av absorbatorbladet som är belägen innanför absorbatorkanalerna 13,14 är försedd med ursparingar 17,18 i form av genomgående hål. I styrstavens övre del 15 är  
5 ursparingarna 17 väsentligt bredare i radiell led än ursparingarna 18 i styrstavens nedre del 16. Alla ursparingar har samma utsträckning i axiell riktning. Det är deras respektive radiella utsträckning som varierar. Ursparingarna 17 i den övre delen 15 är lika stora. När styrstaven 2 är  
10 införd i härden är ursparingarna 17,18 moderatorfyllda, varvid utbränningen, p g a den goda modereringen, ökar ytterligare för bränslekutsarna som står på tur att blottläggas vid nästa tillfälle som styrstaven 2 ska dras ut en bit. För styrning av styrstaven 2 i de relativt smala  
15 spalterna 5a,5b mellan bränslepatronerna 1 är den upptill försedd med styrdynor 19 i form av utåt från bladet sig sträckande bulor. Dessutom är styrstaven 2 försedd med ett handtag 20 för hantering av styrstaven vid inmontering och utbyte.

20

Det enda som skiljer styrstaven 2 i figur 2b från den i figur 2a är att i den nedre delen 16, i närheten av kopplingsstången 12, är en ursparing 21 anordnad som är väsentligt bredare i radiell led än de övriga ursparingarna 18 i den  
25 nedre delen 16 och absorbatorkanalerna 14 som gjorts motsvarande kortare. En fördel med denna utföringsform är att en viss ökad utbränning av bränslestavarna 3 närmast styrstavens 2 korscentrum 10 uppnås så länge styrstaven 2 är helt införd. En annan fördel med denna utföringsform är att  
30 behovet av reaktivitetskontroll i området kring ursparingen 21 minskar eftersom härden oftast har en manteljon, d v s ett område med låganrikat uran, i botten. Ytterligare en fördel med denna utföringsform är att den inbesparade vikten hos styrstaven 2 kan användas till att placera mer  
35 absorbatormaterial i en del av styrstaven 2 där det bättre kommer till nytta. Det senare är mest angeläget då ett tungt absorbatormaterial som hafnium används.

I figur 2c visas en utföringsform av uppfinningen där ursparingarna 17a, 17b, 17c i den övre delen 15 av styrstaven successivt ökar i bredd och absorbatorkanalerna 13a, 13b, 13c successivt minskar i längd ju närmare toppen av styrstaven som de är anordnade. Fördelen med att absorbatorhalten successivt avtar mot toppen av styrstaven är att detta ger en gradvis och mer ideal ökning av belastningen på bränslekutsarna när styrstaven dras ut. Nackdelen med denna utföringsform är att den är mer komplicerad att tillverka i jämförelse med de ovan nämnda utföringsformerna

Figur 2d visar en styrstav 2 där vart och ett av absorbatorbladen 6,8 är försett med ett stort antal kanaler 22, 23, 24 som sträcker sig i styrstavens längdriktning från nedre delen och upp mot övre delen av styrstaven 2. Kanalerna 22, 23, 24 är fyllda med ett absorbatormaterial. Ett antal kanaler 22 är anordnade i den yttre delen av de respektive absorbatorbladen 6,8 och sträcker sig utmed styrstavens aktiva längd. En eller flera kanaler 23, 24 är anordnade närmast korscentrumet 10 och är kortare än kanalerna 22 i den yttre delen av de respektive absorbatorbladen. I den övre delen 15 är ursparingar 17a, 17b, 17c anordnade som är bredare än de ursparingar 18 som är anordnade i styrstavens nedre del 16. Kanalerna 23, 24 närmast korscentrumet 10 slutar nedanför de bredare ursparingarna 17a, 17b, 17c och eventuellt ovanför infästningen av kopplingsstången 12. Absorbatorkanalerna 22, 23 och 24 är förträdesvis cirkulär cylindriska till sin form och har alla samma diameter d.

Styrstaven 2 enligt uppfinningen är lämplig att användas som komplement till konventionella styrostavar. Styrstaven enligt uppfinningen är särskilt lämplig att användas som reglerstav, för reglering av reaktoreffekt och för utbränningskompensation, jämför beskrivning under teknikens ståndpunkt. Reglerstavarna är under en stor del av driftcykeln inskjutna i hårdan. För att uppnå de ovan angivna fördelarna med uppfinningen jämfört med en konventionell styrostav, d v s minskad risk för bränsleskador på kapslingsröret, bättre utnyttjande av bränsle och längre

livslängd för styrestaven, kan det räcka med ett fåtal styrestavar enligt uppfinningen, t ex 4, 8, 12 eller 16, beroende på härdens storlek och sätt att utnyttja styrestavarna. En reaktors avställningsmarginal, d v s den inbyggda underskottsreaktiviteten hos reaktorn som gör att den blir säkert avställd, försämras av styrestavar som är inskjutna i härden under drift. Då endast ett fåtal av styrestavarna i härden är av en typ enligt uppfinningen blir försämringen av avställningsmarginalen liten.

## PATENTKRAV

1. Styrstav (2) för en kokarvattenreaktor innefattande fyra  
absorbatorblad (6,7,8,9) som bildar ett rätvinkligt kors med  
5 ett korscentrum (10), där absorbatorbladens bredd  
sammanfaller med styrstavens radiella riktning och  
absorbatorbladens längd sammanfaller med styrstavens axiella  
riktning, och där vart och ett av absorbatorbladen innefattar  
ett i längdriktningen fördelat absorbatormaterial, varvid ett  
10 medelvärde av mängden absorbatormaterial per längdenhet av  
styrstaven är mindre i styrstavens övre del än i dess nedre  
del, **kännetecknad av** att vardera absorbatorbladet i  
sin övre del (15) innefattar en inre del anordnad radiellt  
innanför en yttre del, där den yttre delen är försedd med  
15 absorbatormaterialet medan den inre delen saknar absorbator-  
material, varvid nämnda inre del i åtminstone något parti  
utgör minst en fjärdedel av absorbatorbladets bredd.

2. Styrstav enligt patentkrav 1, **kännetecknad av** att  
20 den övre delens (15) längd utgör högst en tredjedel av  
absorbatorbladets längd.

3. Styrstav enligt patentkrav 1 eller 2, **kännetecknad  
av** att nämnda inre del i åtminstone något parti utgör minst  
25 en tredjedel av absorbatorbladets bredd.

4. Styrstav enligt något av föregående patentkrav,  
**kännetecknad av** att ett flertal ursparingar  
(17,17a,17b,17c,18) är anordnade i nämnda inre del av  
30 absorbatorbladet.

5. Styrstav enligt patentkrav 4, **kännetecknad av** att  
flertalet av ursparingarna (17,18) är anordnade längs med  
korscentrumet (10), varvid ursparingarna (17) i den övre  
35 delen (15) är bredare än åtminstone huvuddelen av  
ursparingarna (18) i absorbatorbladets nedre del (16).

6. Styrstav enligt något av föregående patentkrav,  
**kännetecknad av** att absorbatorbladen innefattar ett

flertal radiellt anordnade kanaler (13,14) i vilka absorbatormaterialet är anordnat, varvid åtminstone huvuddelen av kanalerna (13) i den övre delen (15) är kortare än kanalerna (14) i den nedre delen (16) av absorbatorbladen.

5 7. Styrstav enligt patentkrav 6, **kännetecknad** av att kanalerna (13,14) i den övre delen (15) och den nedre delen (16) har en diameter (d) av väsentligen lika storlek.

10 8. Styrstav enligt något av patentkraven 1-5, **kännetecknad** av att absorbatorbladen (6,7,8,9) innefattar ett flertal i förhållande till styrstaven axiellt anordnade kanaler (22,23,24) i vilka absorbatormaterialet är anordnat, varvid åtminstone huvuddelen av kanalerna (22) är  
15 anordnade, radiellt utanför en eller flera kanaler (23, 24) vilka är anordnade närmast korscentrumet (10).

9. Styrstav enligt patentkrav 8, **kännetecknad** av att kanalerna (23,24) anordnade närmast korscentrumet (10) är  
20 kortare än kanalerna (22) anordnade i den radiellt utanför anordnade yttre delen av absorbatorbladen (6,7,8,9).

10. Styrstav enligt patentkrav 9, **kännetecknad** av att kanalerna (23,24) anordnade närmast korscentrumet (10) och  
25 kanalerna (22) anordnade i den radiellt utanför anordnade yttre delen av absorbatorbladen (6,7,8,9) har en diameter (d) av väsentligen lika storlek.

11. Styrstav enligt något av föregående patentkrav,  
30 **kännetecknad** av att absorbatormaterialet utgörs av bor och/eller hafnium.

12. Styrstav enligt något av föregående patentkrav, **kännetecknad** av att absorbatormaterialet utgörs av  
35 borkarbid och/eller hafniummetall.

## SAMMANFATTNING

Styrstav (2) för en kokarvattenreaktor innefattande fyra  
absorbatorblad (6,7,8,9) som bildar ett rätvinkligt kors med  
5 ett korscentrum (10). Absorbatorbladens bredd sammanfaller  
med styrstavens radiella riktning och absorbatorbladens längd  
sammanfaller med styrstavens axiella riktning. Vart och ett  
av absorbatorbladen innefattar ett i längdriktningen fördelat  
absorbatormaterial, varvid ett medelvärde av mängden  
10 absorbatormaterial per längdenhet av styrstaven är mindre i  
styrstavens övre del än i dess nedre del. Vart och ett av  
absorbatorbladen innefattar i sin övre del (15) en inre del  
anordnad radiellt innanför en yttre del, där den yttre delen  
är försedd med absorbatormaterial medan den inre delen saknar  
15 absorbatormaterial, varvid nämnda inre del i åtminstone något  
parti utgör minst en fjärdedel av absorbatorbladets bredd.  
(Figur 2a)

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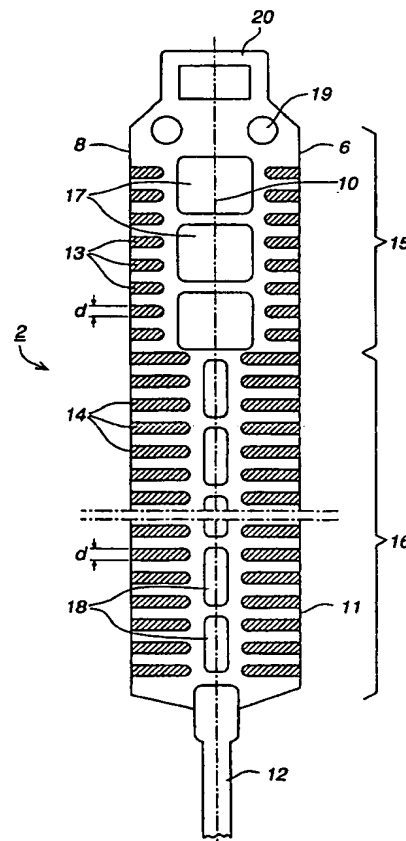
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(54) Title: CONTROL ROD

(57) Abstract

A control rod (2) for boiling water reactor comprising four absorber blades (6, 7, 8, 9) which form an orthogonal cross with a cruciform centre (10). The width of the absorber blades coincides with the radial direction of the control rod and the length of the absorber blades coincides with the axial direction of the control rod. Each one of the absorber blades comprises an absorber material distributed in the longitudinal direction, whereby a mean value of the quantity of absorber material per unit of length of the control rod is smaller in the upper part of the control rod than in the lower part thereof. Each one of the absorber blades comprises in its upper part (15) an inner part arranged radially inside an outer part, where the outer part is provided with absorber material whereas the inner part lacks absorber material, whereby said inner part in at least some portion constitutes at least one-fourth of the width of the absorber blade.





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Control rod

## TECHNICAL FIELD

5 The present invention relates to a control rod for a boiling water reactor comprising four absorber blades forming an orthogonal cross. The absorber blades contain absorber material distributed in the longitudinal direction, a mean value of the quantity of absorber material per unit of length  
10 of the control rod being smaller in the upper part of the control rod than in the lower part thereof.

## BACKGROUND ART

15 A core in a boiling water reactor normally comprises several hundred fuel assemblies. These are arranged vertically in the core and have an at least substantially square cross section. Each fuel assembly comprises a bundle of fuel rods. In boiling water reactors, fuel bundles containing 8x8,  
20 9x9 or 10x10 fuel rods are often used. A fuel bundle is surrounded by a fuel channel. The fuel channel is open at both ends so as to allow the coolant of the reactor to flow through the fuel bundle. The core is immersed into water which serves both as coolant and as neutron moderator. Each  
25 fuel rod contains a large number of fuel pellets stacked on top of each other in a cladding tube.

A nuclear reactor also comprises a plurality of control rods, the primary task of which is to start, control and shut off  
30 the power generation by being inserted into and extracted from the reactor core. In the boiling water reactor, the control rods are inserted into the core from below. With the aid of a drive, the control rod may be operated in different positions between a fully extracted and a fully inserted  
35 position in the core. Certain of the control rods are extracted from the core during operation, whereas others are

inserted to different levels. These levels vary during the operating cycle of the reactor. In the boiling water reactor, the control rods are composed of four vertically arranged elongated absorber blades, which together form an orthogonal cross. The absorber blades are generally of stainless steel and provided with a large number of bored holes or tubes filled with a neutron-absorbing material, for example boron carbide ( $B_4C$ ) or hafnium. The absorber material is usually uniformly distributed in both the axial and radial directions in the absorber blades. The active length of the control rods, that is, the length of that part of the control rod which contains the absorber material, corresponds to the active height of the reactor core when the control rods are fully inserted into the core.

The fuel assemblies are arranged in a regular lattice, where each fuel assembly is included in two rows of fuel assemblies which are perpendicular to each other. The control rods are normally arranged with each one of their absorber blades between two fuel assemblies located in the same row, such that each control rod together with four fuel assemblies arranged around its blades form one unit.

The control rods in the reactor are usually divided into two groups with different tasks. One group of control rods is, during normal operation, fully extracted from the core and used only for stopping and starting the reactor. The other group is used for controlling the reactor power and for burnup compensation during normal reactor operation. The control rods in the second group will hereinafter be referred to as controlling rods. These controlling rods normally constitute less than 10% of all the control rods. At the beginning of an operating cycle, the controlling rods are inserted. By an operating cycle is meant the time between two refuellings. To compensate for the burnup of the fuel, the controlling rods are successively extracted during the

operating cycle. The change of the positions of the controlling rods takes place at certain time intervals, for example once a week. The change may, for example, consist of the controlling rods being extracted about 8% of their  
5 lengths.

Currently, conventional control rods are used, with the absorber material uniformly distributed in the absorber blades, in both groups of control rods. During the time when  
10 the controlling rods are inserted, those fuel pellets which are located adjacent to the absorber blades are protected from burnup of fissile material. This leads to a situation where, each time the controlling rod is extracted a certain distance, fuel pellets containing high contents of fissile  
15 material are exposed, resulting in a considerable increase in power in these fuel pellets. This local increase in power takes place very rapidly. Such stresses may in certain cases cause fuel failure, so-called PCI failure (PCI = pellet-clad interaction), on the cladding tube surrounding the fuel  
20 pellets. The fuel rods which are located nearest the cruciform centre of the controlling rod are particularly subjected to such stresses and hence run the greatest risk of fuel failure. The reason for this is that these fuel rods are protected against burnup of fissile material by two absorber  
25 blades.

From US patent application No. 367 099, a control rod is known which in its upper part is arranged with a smaller percentage of absorber material per unit of length than the  
30 rest of the control rod. In this way, part of the fissile material is burnt up during the time when the control rod is fully inserted into the core and the power increase is not equally great when the controlling rod is extracted. A reduced power increase when the controlling rod is extracted  
35 is achieved by arranging a larger number of bored channels perpendicular to the longitudinal direction of the control

rod and filling them with a neutron-absorbing material, whereby the channels in the upper part of the control rod have a relatively smaller radius, whereby the length of the respective channel is considerably larger than its radius, whereas the other channels have a relatively larger radius.

One disadvantage of the above-mentioned control rod is that the reduction of the power increase obtained when the control rod is extracted is not sufficiently great to eliminate the risk of fuel failure on the most exposed fuel rods, that is the fuel rods situated nearest the cruciform centre of the control rod.

Another disadvantage is that the service life becomes shorter for the above-mentioned control rod than for conventional control rods. The service life of the absorber material, and hence the service life of the control rod, depend on the quantity of absorber material per unit of surface. For a cylindrical channel, the length of which is considerably larger than its radius, the service life of the absorber material is substantially influenced by its radius. A reduction of the diameters of the channels leads to a corresponding reduction of the service life of the control rod.

From US patent application No. 659 436, it is known to arrange a smaller quantity of absorber material in that part of the absorber blades which extends along the fuel rods located nearest to the cruciform centre. In their outer part, the blades are provided with a larger number of channels, filled with absorber material, which extend perpendicular to the longitudinal direction of the control rod. In one embodiment, that part of the absorber blades which is located inside the filled channels lacks absorber material. The control rod is provided with recesses, which extend across the fuel rod located nearest the cruciform centre. These

recesses are filled with moderator such that the consumption of fissile material in adjacent fuel rods increases. By arranging the absorber material in this way, it is possible to considerably extend the duration of an operating cycle for a reactor.

The disadvantage of using such a control rod as a controlling rod is that the risk of fuel failure admittedly has been reduced for the most exposed fuel rods, that is, those located nearest the cruciform centre, but the risk of fuel failure on the other fuel rods is unchanged compared with the risk of fuel failure when using conventional control rods.

#### SUMMARY OF THE INVENTION

The object of the invention is to achieve a control rod for a nuclear reactor which provides a reduced risk of fuel failure when, from an inserted position for a longer period of time, it is extracted from the reactor core in successive steps.

What characterizes a control rod according to the invention will become clear from the appended claims.

A control rod according to the invention has absorber blades which form an orthogonal cross with a central cruciform centre, the capacity of which to absorb neutrons varies both axially and radially. The capacity of the absorber blades to absorb neutrons is lower in their upper part than in their lower part. In the upper part of the absorber blades, the neutron absorption capacity is higher in its outer part than in its inner part which adjoins the cruciform centre. The control rod according to the invention leads to the power reduction for fuel pellets located adjacent to the upper part of the control rod becoming smaller in relation to fuel pellets which are not controlled with respect to fission velocity with the aid of control rods. Especially those fuel

pellets which are located nearest the cruciform centre of the control rod will have a lower power reduction than those fuel pellets which are not controlled with the aid of control rods. When the control rod is extracted somewhat, and the fuel pellets which have been protected by the upper part of the control rod are exposed, the power increase in these fuel pellets will be smaller than for prior art control rods, which is due to the fuel pellets already being burnt up to a certain extent.

One advantage of a control rod according to the invention is that the risk of fuel failure on the cladding tube in connection with the control rod being extracted is reduced. Another advantage is that the utilization of the fuel becomes more efficient. An additional advantage is that longer service lives of the control rods are made possible.

In a control rod according to the invention, each one of the absorber blades comprises an upper and a lower part, the mean value of the contents of absorber material per unit of length of the control rod being smaller in the upper part of the control rod than in the lower part thereof. The upper part comprises an outer part provided with absorber material and an inner part which lacks absorber material and which is arranged radially inside the outer part.

To achieve the advantages of the invention, at least some portion of the above-mentioned inner part should constitute at least one-fourth of the width of the absorber blade in the radial direction. In an especially advantageous embodiment, at least some portion of the above-mentioned inner part should constitute at least one-third of the width of the absorber blade in the radial direction. The area, in a section across the longitudinal direction of the control rod, of the above-mentioned inner part should be at least 25% of the area of the upper part. In an especially advantageous

- embodiment, the area, in a section across the longitudinal direction of the control rod, of the above-mentioned inner part should be at least 30% of the area of the upper part. The length of the upper part should not exceed one-third of the total length of the absorber blade.
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- In a preferred embodiment of the invention, recesses in the form of through-holes are arranged in the inner central parts of the upper part of the control rod. This implies that more neutron moderator is supplied to the upper central part of the control rod, which further increases the burnup of fissile material in the fuel rods which are arranged nearest the cruciform centre of the control rod.
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15 BRIEF DESCRIPTION OF THE DRAWINGS

- Figure 1 shows, in a horizontal section, a small part of a reactor core of a boiling water reactor, more specifically a cross section through four fuel assemblies with a control rod placed centrally therebetween.
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Figures 2a - 2d show, in vertical sections, different embodiments of a control rod according to the invention.

25 DESCRIPTION OF THE PREFERRED EMBODIMENTS

- Figure 1 shows a horizontal section through four fuel assemblies 1 with an associated control rod 2 placed therebetween. The section is laid through the upper part of the control rod 2. Each fuel assembly 1 comprises 10x10 fuel rods 3. The fuel rods 3 are enclosed in a fuel channel 4 with a square cross section. Each fuel rod 3 comprises a number of fuel pellets of uranium dioxide stacked on top of each other and enclosed in a cladding tube. The spaces between the fuel rods 3 in the fuel assembly 1 is traversed by water which constitutes both coolant and moderator. Between the fuel
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assemblies 1, gaps 5a and 5b are formed which are traversed by water. The control rod 2 is inserted into the gaps 5a and 5b and has four absorber blades 6, 7, 8, 9 which form an orthogonal cross. The cruciform centre of the control rod is designated 10.

Figure 2a shows a vertical section through a control rod 2 according to the invention. The control rod 2 is substantially made of stainless steel and comprises an absorber part 11, which is supported by a vertical coupling bar 12. The control rod 2 comprises an upper part 15 and a lower part 16. The length of the upper part constitutes at most one-third of the total length of the absorber part 11. Two of the four absorber blades 6 and 8 are visible in Figure 2a. Each one of the absorber blades 6, 8 is provided with a large number of bored channels 13, 14 extending perpendicularly to the longitudinal direction of the control rod 2, from the outer edge of the absorber blade 6, 8 and towards the cruciform centre 10. Each channel 13, 14 is filled with an absorber material, for example natural or enriched boron carbide and/or metallic hafnium, gadolinium or erbium, and is hermetically sealed outwards by means of, for example, welding. In the following, these channels will be referred to as absorber channels. The absorber channels 13 which are arranged in the upper part 15 of the absorber blades are considerably shorter than the absorber channels 14 which are arranged in the lower part 16 of the absorber blades. The absorber channels 13 are arranged in an outer part, disposed radially outside an inner part, of the upper part 15 of the absorber blade. The absorber channels 13 each have a length which is at least 30% shorter than the length of one of the absorber channels 14 in the lower part 16.

The absorber channels 13, 14 in the upper part 15 and in the lower part 16 of the absorber blades, respectively, are preferably circularly cylindrical in shape and all have the

same diameters  $d$ . To obtain a maximum service life, the diameters  $d$  of the absorber channels 13, 14 should be the largest possible taking into consideration the thickness of the material of the absorber blades. The service life of the absorber material depends on the quantity of absorber material per unit of surface, described under the background art above. On the other hand, a halving of the length of the absorber channel with a retained diameter  $d$  only has a marginal effect on the service life. In this way, the service life of the control rod is retained in spite of the fact that the percentage of absorber material is reduced in its upper part.

That part of the absorber material which is located inside the absorber channels 13, 14 is provided with recesses 17, 18 in the form of through-holes. In the upper part 15 of the control rod, the recesses 17 are considerably wider in the radial direction than the recesses 18 in the lower part 16 of the control rod. All the recesses have the same extent in the axial direction. It is their respective radial extent that varies. The recesses 17 in the upper part 15 are equally large. When the control rod 2 is inserted into the core, the recesses 17, 18 are filled with moderator, whereby the burnup - due to the good moderation - increases further for the fuel pellets which are to be exposed the next time the control rod 2 is to be extracted somewhat. For guiding the control rod 2 in the relatively narrow gaps 5a, 5b between the fuel assemblies 1, it is provided on top with guide pads 19 in the form of bulges extending outwards from the blade. In addition, the control rod 2 is provided with a handle 20 for handling the control rod during installation and replacement.

The only thing that distinguishes the control rod 2 in Figure 2b from that in Figure 2a is that in the lower part 16, in the vicinity of the coupling bar 12, a recess 21 is arranged which is considerably wider in the radial direction than the other recesses 18 in the lower part 16 and the absorber

channels 14 which have been made correspondingly shorter. One advantage of this embodiment is that a certain increased burnup of the fuel rods 3 nearest the cruciform centre 10 of the control rod 2 is achieved as long as the control rod 2 is fully inserted. Another advantage of this embodiment is that the need of reactivity control in the area around the recess 21 decreases since the core normally has a blanket ion, that is, a region with uranium with low enrichment, at the bottom. An additional advantage with this embodiment is that the saved weight of the control rod 2 may be used for placing more absorber material in a part of the control rod 2 where it is better utilized. The latter is of more importance when a heavy absorber material, such as hafnium, is used.

Figure 2c shows an embodiment of the invention where the recesses 17a, 17b, 17c in the upper part 15 of the control rod successively increase in width and the absorber channels 13a, 13b, 13c successively decrease in length the closer to the top of the control rod that they are arranged. The advantage of the absorber content successively decreasing towards the top of the control rod is that this gives a gradual and more ideal increase of the load on the fuel pellets when the control rod is extracted. The disadvantage of this embodiment is that it is more complicated to manufacture in comparison with the embodiments mentioned above.

Figure 2d shows a control rod 2 where each one of the absorber blades 6, 8 is provided with a large number of channels 22, 23, 24 extending in the longitudinal direction of the control rod from the lower part and up towards the upper part of the control rod 2. The cooling channels 22, 23, 24 are filled with an absorber material. A number of channels 22 are arranged in the outer part of the respective absorber blades 6, 8 and extend along the active length of the control rod. One or more channels 23, 24 are arranged nearest the cruciform centre 10 and are shorter than the channels 22 in

the outer part of the respective absorber blades. In the upper part 15, recesses 17a, 17b, 17c are arranged which are wider than the recesses 18 which are arranged in the lower part 16 of the control rod. The channels 23, 24 nearest the cruciform centre 10 terminate below the wider recesses 17a, 17b, 17c and possibly above the attachment of the coupling bar 12. The absorber channels 22, 23 and 24 are preferably circularly cylindrical in shape and all have the same diameter d.

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The control rod 2 according to the invention is suitable to use as a complement to conventional control rods. The control rod according to the invention is especially suitable to use as a controlling rod, for control of reactor power and for burnup compensation (cf. the description under the background art). During a considerable part of the operating cycle, the controlling rods are inserted into the core. To attain the above-mentioned advantages of the invention compared with a conventional control rod, that is, reduced risk of fuel failure on the cladding tube, better utilization of fuel and longer service life of the control rod, it may be sufficient with a small number of control rods according to the invention, for example 4, 8, 12 or 16, depending on the size of the core and the manner of utilizing the control rods. The shutdown margin of a reactor, that is, the inherent negative reactivity of the reactor which causes it to be safely shut down, is deteriorated by control rods which are inserted into the core during operation. Since only a small number of the control rods in the core are of a type according to the invention, the deterioration of the shutdown margin becomes small.

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## CLAIMS

1. A control rod (2) for a boiling water reactor comprising four absorber blades (6, 7, 8, 9) forming an orthogonal cross with a cruciform centre (10), where the width of the absorber blades coincides with the radial direction of the control rod and the length of the absorber blades coincides with the axial direction of the control rod, and wherein each one of the absorber blades comprises an absorber material distributed in the longitudinal direction, whereby a mean value of the quantity of absorber material per unit of length of the control rod is smaller in the upper part of the control rod than in the lower part thereof, **characterized** in that each absorber blade in its upper part (15) comprises an inner part arranged radially inside an outer part, where the outer part is provided with the absorber material whereas the inner part lacks absorber material, whereby said inner part, in at least some portion, constitutes at least one-fourth of the width of the absorber blade.
2. A control rod according to claim 1, **characterized** in that the length of the upper part (15) constitutes at most one-third of the length of the absorber blade.
3. A control rod according to claim 1 or 2, **characterized** in that said inner part in at least some portion constitutes at least one-third of the width of the absorber blade.
4. A control rod according to any of the preceding claims, **characterized** in that a plurality of recesses (17, 17a, 17b, 17c, 18) are arranged in said inner part of the absorber blade.
5. A control rod according to claim 4, **characterized** in that a plurality of the recesses (17, 18) are arranged along the cruciform centre (10), whereby the recesses (17) in the

upper part (15) are wider than at least the majority of the recesses (18) in the lower part (16) of the absorber blade.

6. A control rod according to any of the preceding claims,  
5 **characterized** in that the absorber blades comprise a plurality of radially arranged channels (13, 14) in which the absorber material is arranged, whereby at least the majority of the channels (13) in the upper part (15) are shorter than the channels (14) in the lower part (16) of the  
10 absorber blades.

7. A control rod according to claim 6, **characterized** in that the channels (13, 14) in the upper part (15) and the lower part (16) have a diameter (d) of essentially equal size.  
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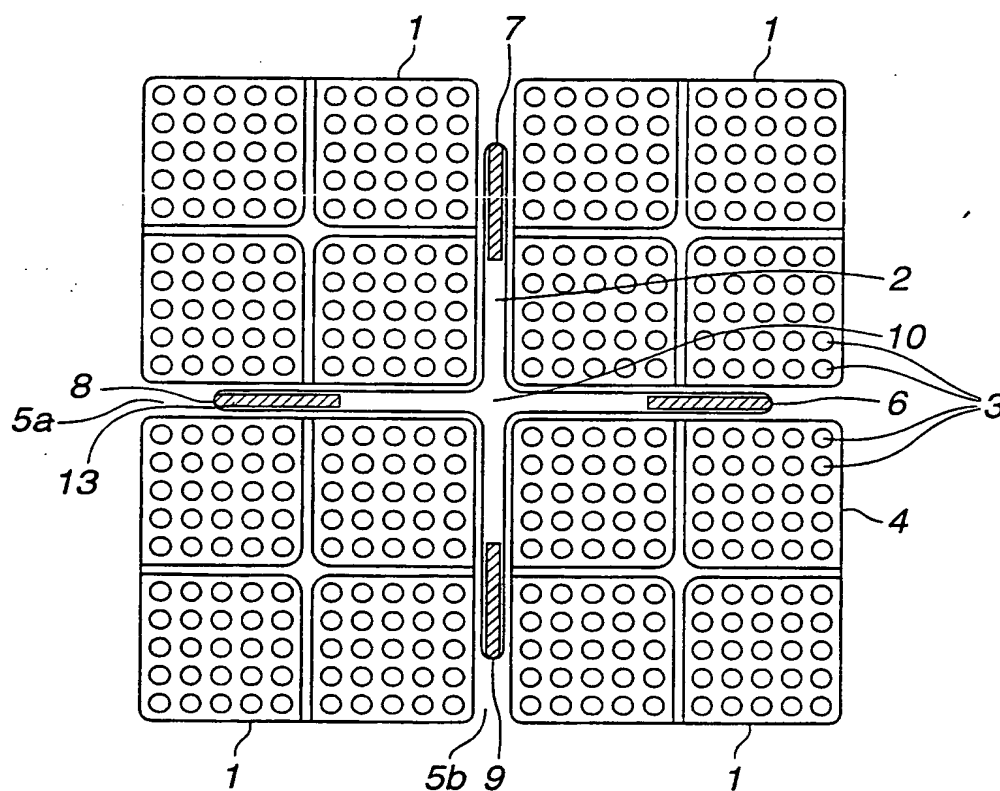
8. A control rod according to any of claims 1-5, **characterized** in that the absorber blades (6, 7, 8, 9) comprise a plurality of channels (22, 23, 24), arranged axially in relation to the control rod, in which the  
20 absorber material is arranged, whereby at least the majority of the channels (22) are arranged radially outside one or more channels (23, 24) which are arranged nearest the cruciform centre (10).

9. A control rod according to claim 8, **characterized** in that the channels (23, 24) arranged nearest the cruciform centre (10) are shorter than the channels (22) arranged in outer part of the absorber blades (6, 7, 8, 9), arranged radially outside said cruciform centre.  
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10. A control rod according to claim 9, **characterized** in that the channels (23, 24) arranged nearest the cruciform centre (10) and the channels (22) arranged in the outer part of the absorber blades (6, 7, 8, 9), arranged radially  
35 outside said cruciform centre, have a diameter (d) of essentially equal size.

11. A control rod according to any of the preceding claims, characterized in that the absorber material consists of boron and/or hafnium.

5 12. A control rod according to any of the preceding claims, characterized in that the absorber material consists of boron carbide and/or hafnium metal.

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*Fig. 1*



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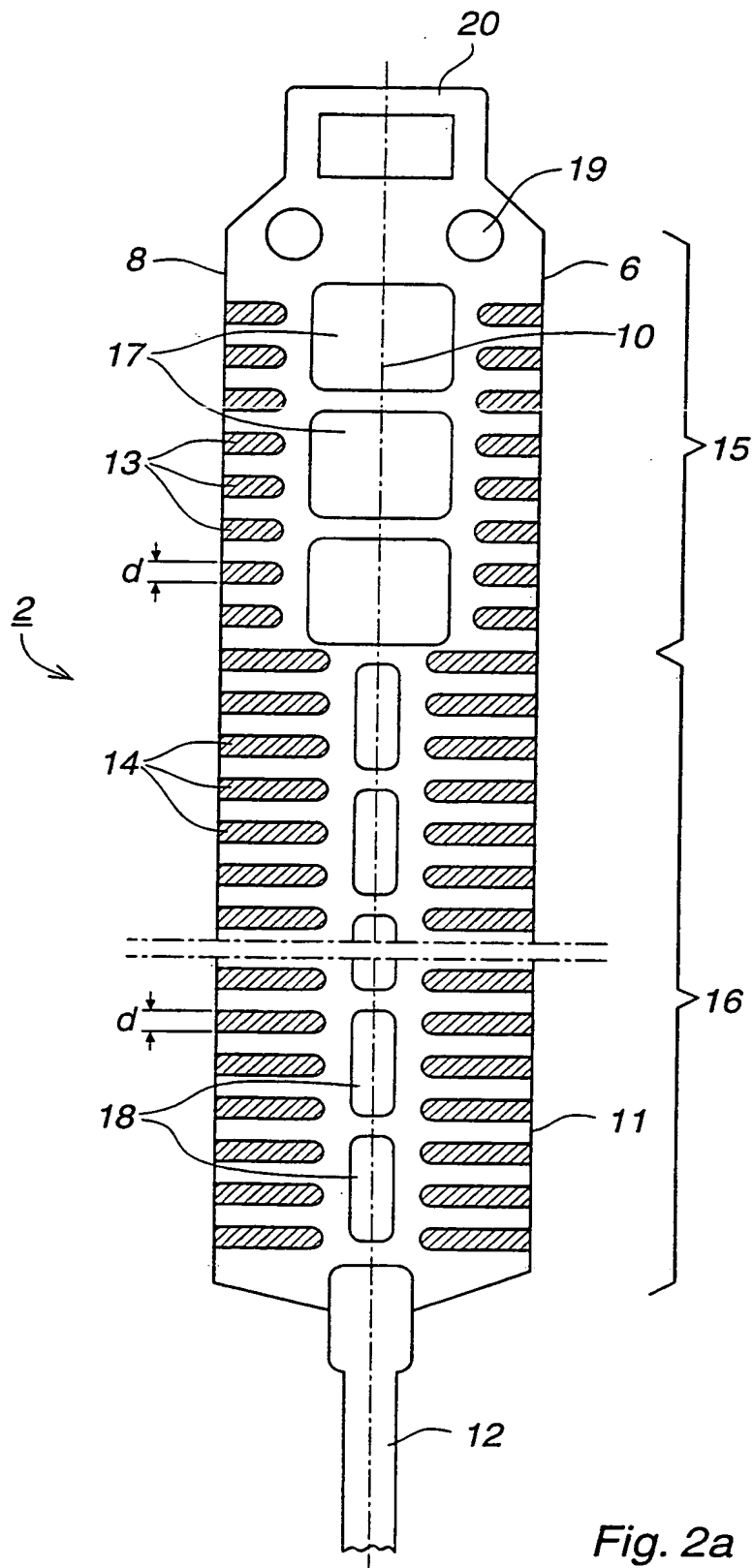


Fig. 2a

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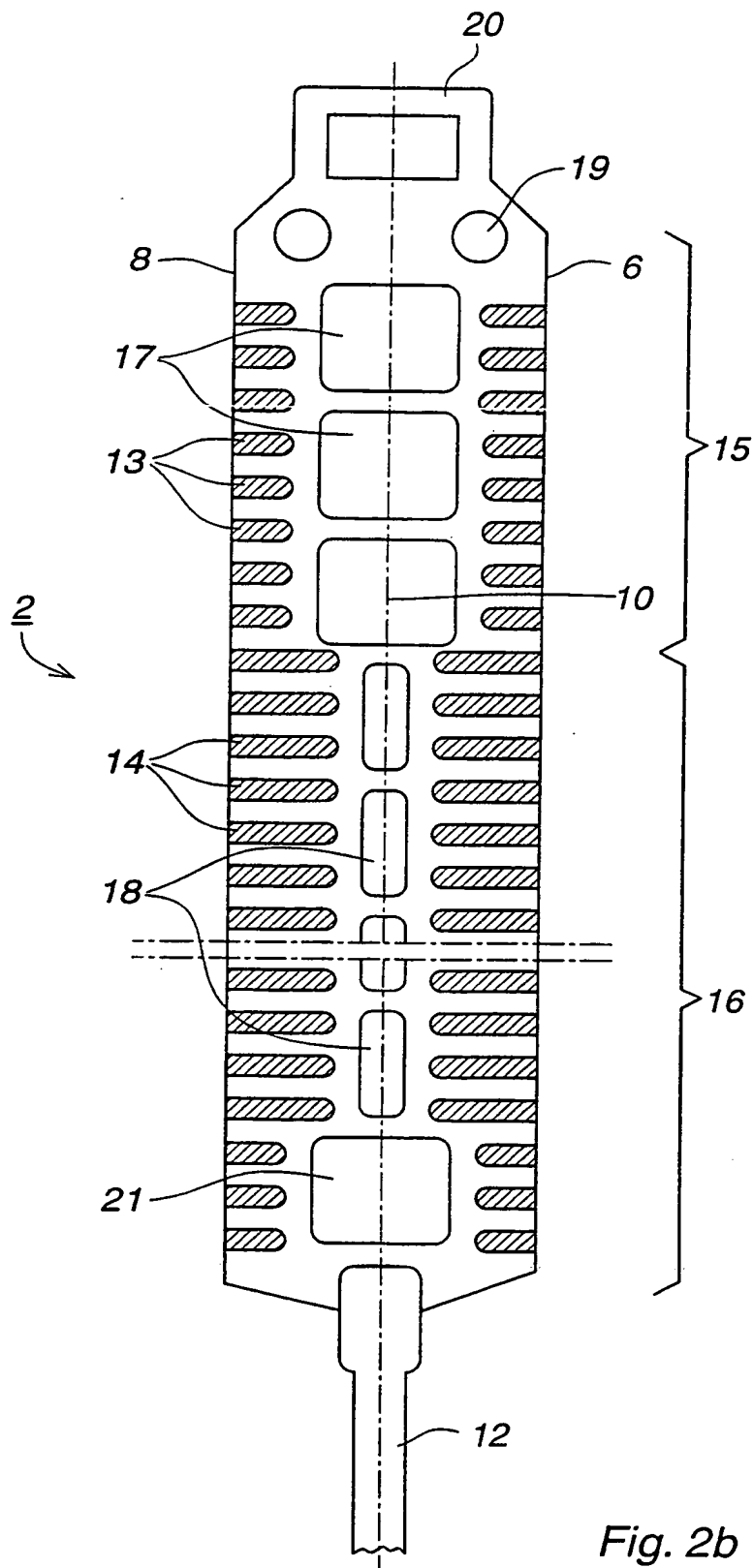
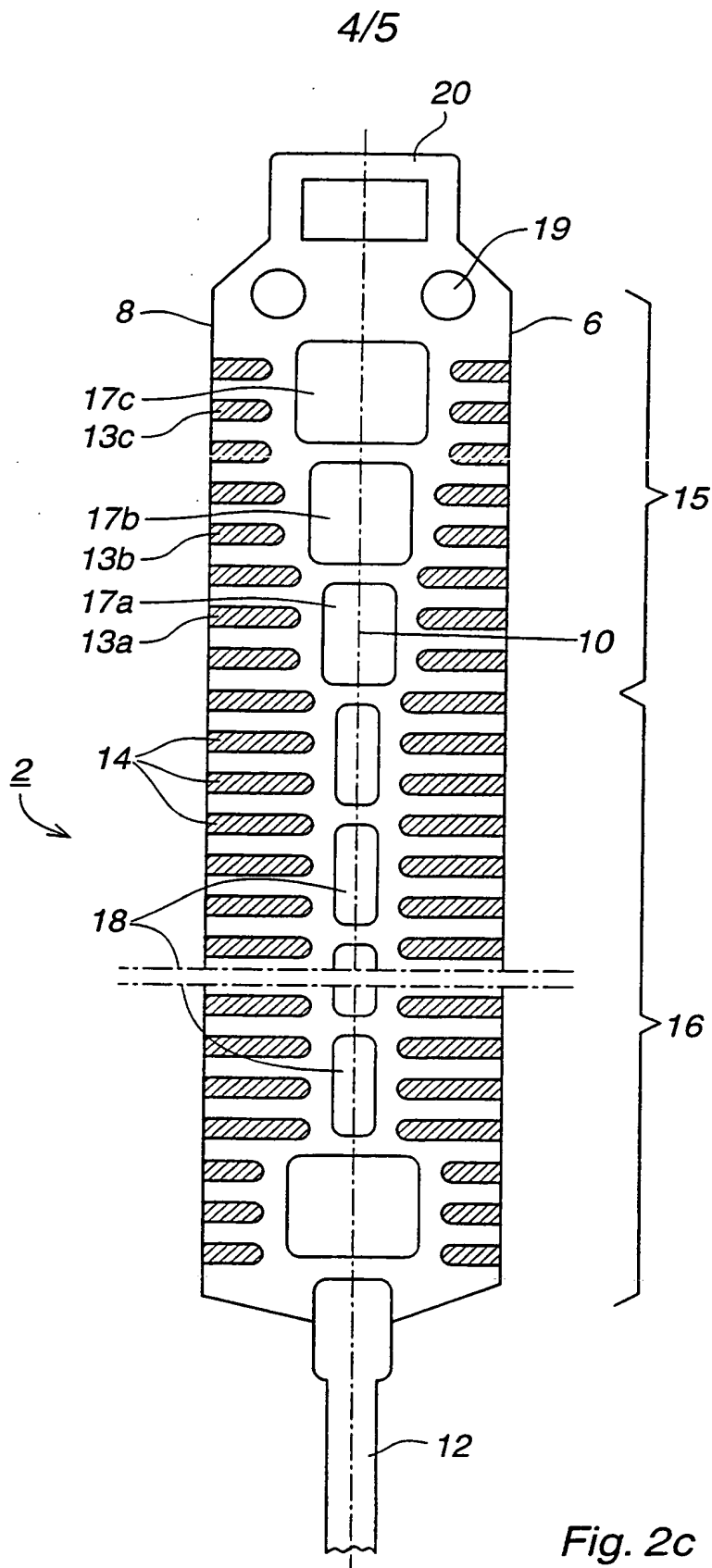


Fig. 2b



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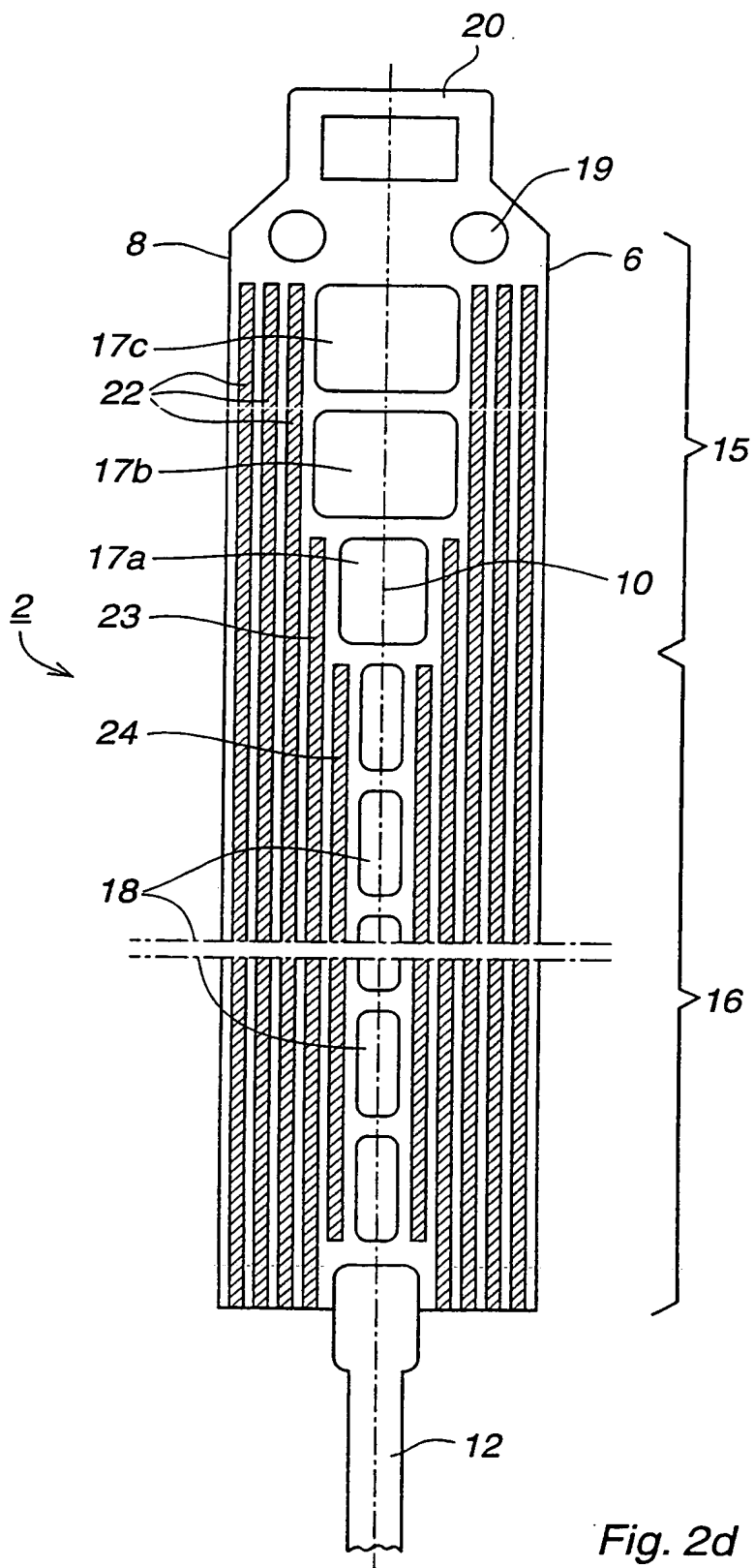


Fig. 2d

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 99/02268

## A. CLASSIFICATION OF SUBJECT MATTER

IPC7: G21C 7/113

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: G21C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CH 665046 A5 (AKTIEBOLAGET ASEA-ATOM), 15 April 1988 (15.04.88), page 2, column 1, line 67 - column 2, line 38; page 3, column 1, line 43 - column 2, line 2, figure 2  -----	1-12

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

\* Special categories of cited documents:

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Date of the actual completion of the international search

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### Information on patent family members

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